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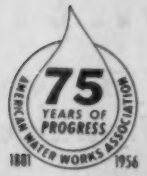

Journal

VOL. 48 • NO. 5

AMERICAN WATER WORKS ASSOCIATION

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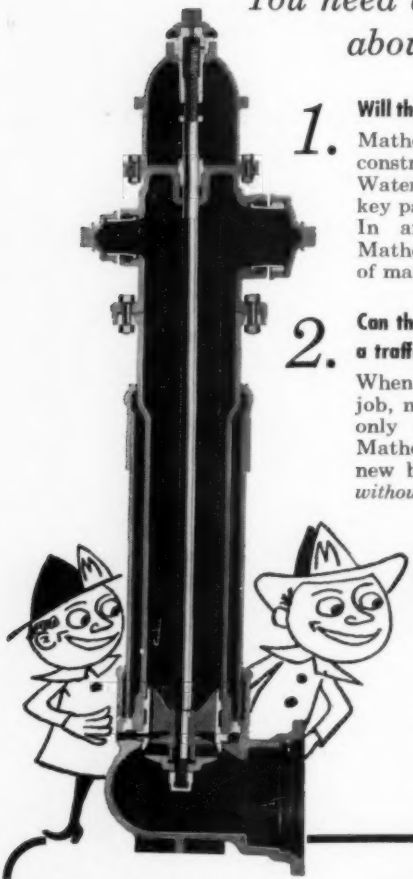

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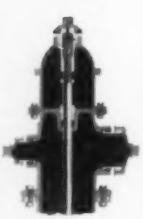

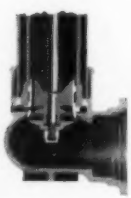

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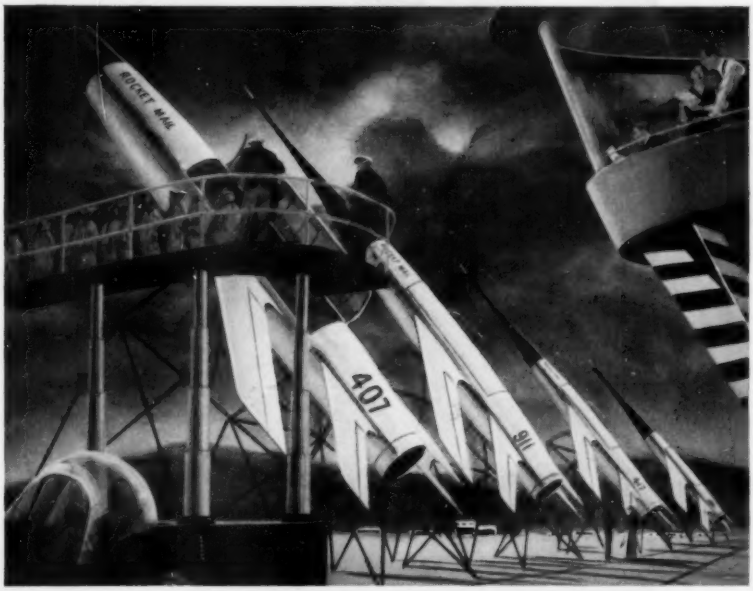

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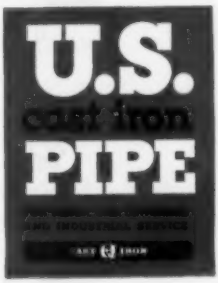

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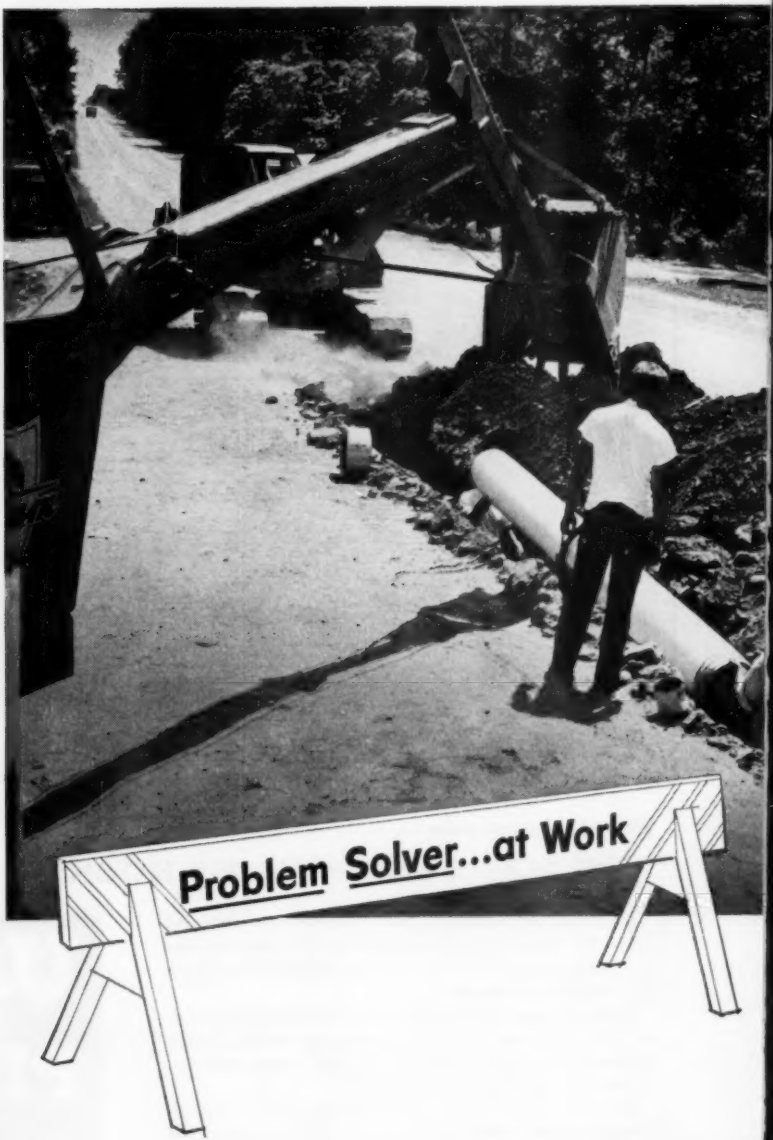

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Sep. 12–14—New York Section, at Sagamore Inn, Bolton Landing, Lake George. Secretary, Kimball Blanchard, Rensselaer Valve Co., c/o Ludlow Valve Co., 11 W. 42nd St., New York 17.

Sep. 12–14—Michigan Section, Kalamazoo. Secretary, T. L. Vander Velde, Chief, Water Supply Section, Michigan Dept. of Health, Lansing 4.

Sep. 12–14—North Central Section, at Hotel Lowry, St. Paul, Minn. Secretary, Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

Sep. 17–19—Kentucky-Tennessee Section, at Hotel Patten, Chattanooga, Tenn. Secretary, J. W. Finney Jr., 553 S. Limestone St., Lexington, Ky.

Sep. 19–21—Ohio Section, at Commodore Perry Hotel, Toledo. Secretary, M. E. Druley, Dayton Power & Light Co., Wilmington.

Sep. 26–28—Wisconsin Section, at Stoddard Hotel, La Crosse. Secretary, L. A. Smith, Supt., Water & Sewerage, City Hall, Madison 3.

Sep. 30–Oct. 2—Missouri Section, at Hotel Governor, Jefferson City. Secretary, W. A. Kramer, Rm. 3, 6th Floor, State Office Bldg., Jefferson City.

Oct. 14–17—Southwest Section. at Marion Hotel, Little Rock, Ark. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 18–20—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, C. B. Tygert, Wallace & Tiernan Inc., Box 178, Newark 1.

Oct. 21–24—Alabama-Mississippi Section, at Battle House, Mobile, Ala. Secretary, Irving E. Anderson, Dist. Engr., Surface Water Branch, USGS, Box 2052, Jackson, Miss.

Oct. 22–26—California Section, at U. S. Grant Hotel, San Diego. Secretary, Henry J. Ongerth, Sr. San. Engr., Bureau of San. Eng., 905 Contra Costa Ave., Berkeley 7.

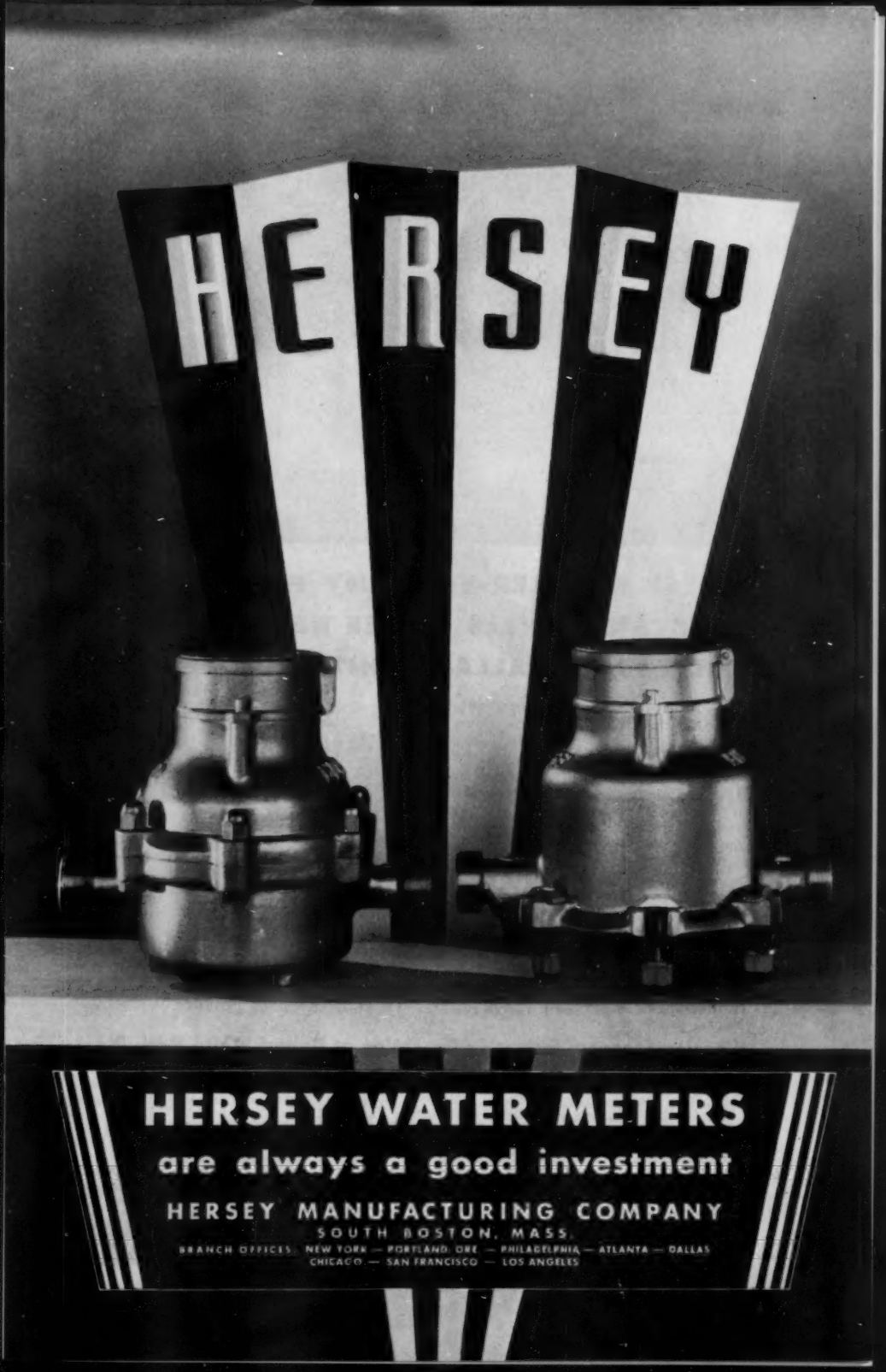
Oct. 24–26—Iowa Section, at Hotel Fort Des Moines, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 24–26—Chesapeake Section, at Southern Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington 15, D.C.

Oct. 31–Nov. 2—West Virginia Section, at Hotel West Virginian, Bluefield. Secretary, Hugh W. Hetzer, Engr. Gen. Office, West Virginia Water Service Co., 179 Summers St., Charleston 1.

Nov. 7–9—Virginia Section, at Chamberlin Hotel, Old Point Comfort. Secretary, J. P. Kavanagh, Dist. Mgr., Wallace & Tiernan Inc., 213 Carlton Terrace Bldg., Roanoke.

Nov. 12–14—North Carolina Section, at Hotel Charlotte, Charlotte. Secretary, Wilbur E. Long Jr., 1615 Bickett Blvd., Raleigh.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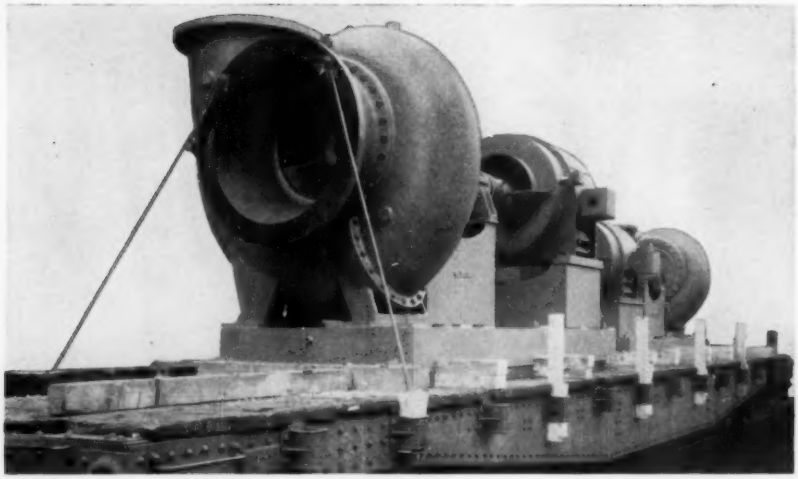

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- 24" x 20" constant speed pump, driven by 200 HP, 2300 volt motor. Capacity 20,000 GPM at 37' TDH.

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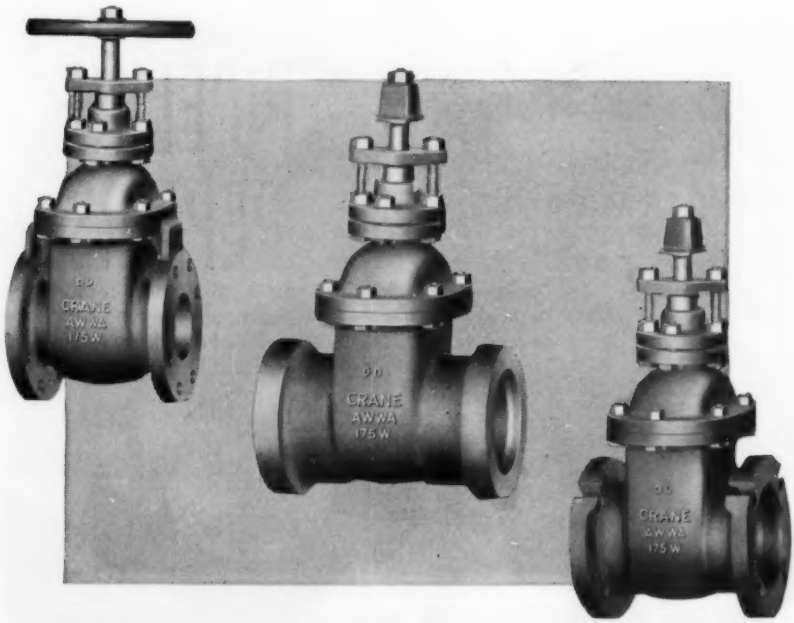

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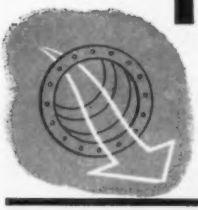

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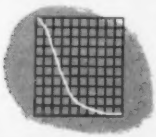

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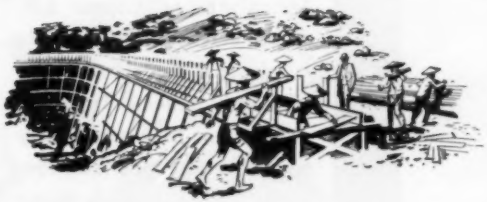

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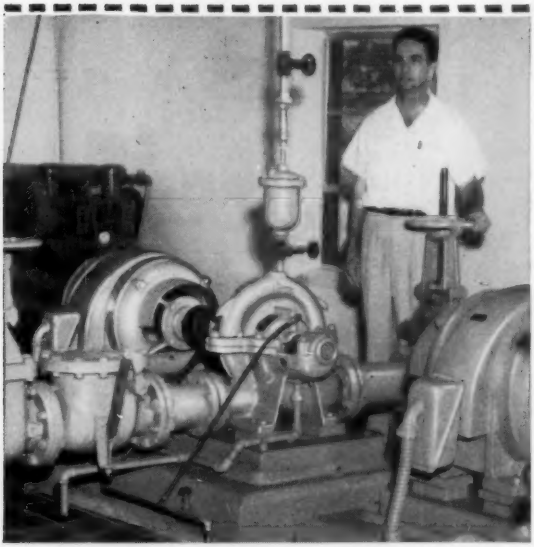
Allis-Chalmers

PUMPS Solve a Public Works Problem



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Duty: 500 gpm at 200-ft head. Power Cost 1.25¢ per kwhr.		
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A Savings of $30.00 a Month		

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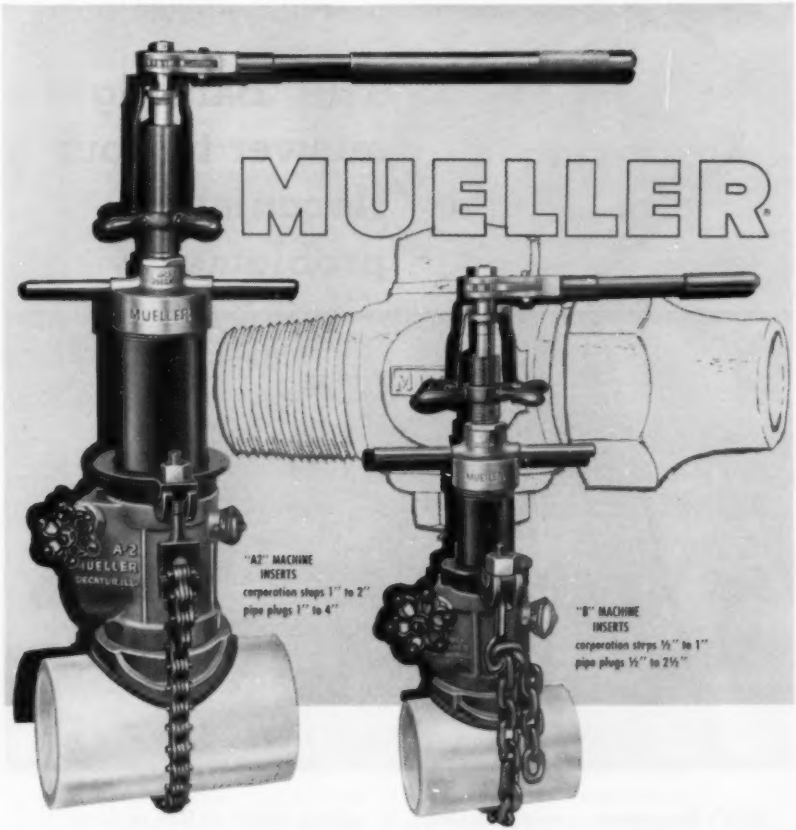

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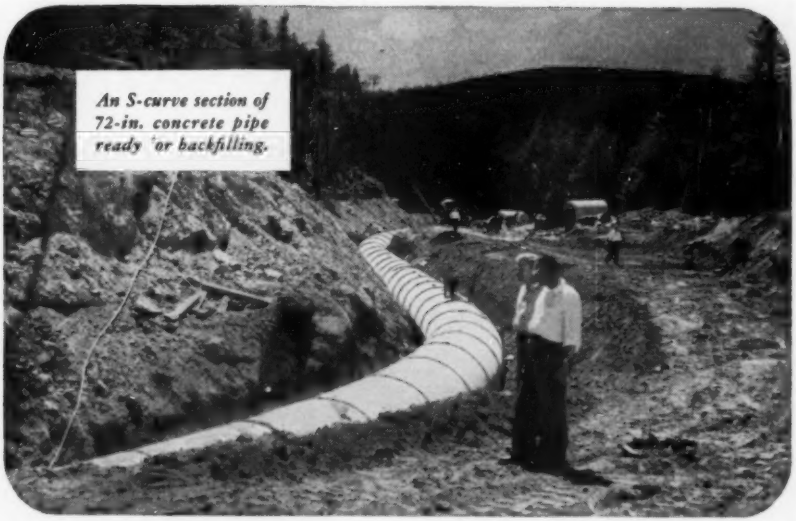
CHAIN BELT COMPANY
Milwaukee 1, Wisconsin



An S-curve section of 72-in. concrete pipe ready for backfilling.

Denver's mounting water needs supplied with 27,000 feet of CONCRETE PIPE

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The project, 80 miles west of Denver, required 27,000 ft. of concrete pipe 30 to 72 in. in diameter. Inasmuch as there was no head on these lines, reinforced concrete sewer pipe, ASTM Specification C-75, was used.

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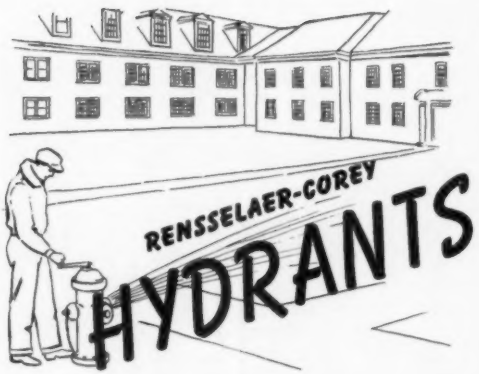

This is the hydrant that has been the standard of excellence in hundreds of cities for many years. Inspectors, maintenance men and fire chiefs, all have their reasons for endorsing the Rensselaer Corey Hydrant.

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This hydrant opens with the pressure, is easy to operate and cannot stick. No digging for repairs, or for standpipe breakage. Now available with any type connection and "O" Ring seal.

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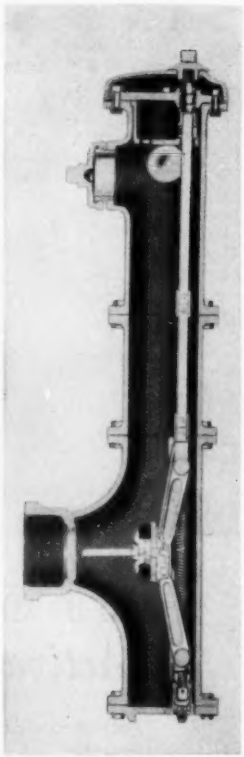

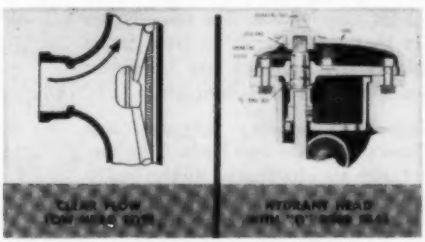

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Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 48 • MAY 1956 • NO. 5

Rates, Revenues, and Rising Costs

Louis R. Howson

A paper presented on Mar. 22, 1956, at the Illinois Section Meeting, Chicago, Ill., by Louis R. Howson, Partner, Alvord, Burdick & Howson, Chicago, Ill.

WATER rates are essentially a means of allocating revenue requirements equitably to all classes of consumers. This discussion deals primarily with revenues rather than rates.

Every water utility, if it is to furnish good service, must have sufficient revenue to cover: [1] all operation and maintenance expenses; [2] depreciation; and [3] fixed charges (or return on investment). In addition, it must earn a surplus large enough to attract the capital necessary for its orderly expansion. The costs of operation and maintenance are in general identical for both privately and municipally owned water works, assuming equally efficient management. Depreciation likewise occurs without regard for ownership, and must be provided for as an annual operating expense chargeable to those using the facilities. The amount of depreciation charged annually should be at least sufficient to maintain the facilities. Although it rarely does so under regulatory commission control, it should also take into consideration the changing purchasing value of the dollar. Regulatory commissions now generally allow 1.5–2.0 per cent of original cost for annual depreciation in fixing rates for private water works. This is approximately equivalent to 0.75–1.0 per cent of the actual current cost of reproduction. Because it is facilities rather than dollars that furnish water service, it is facilities that are consumed and must be replaced when worn out: obviously, they can only be replaced with current dollars. Accrual of depreciation in amounts sufficient only to repay original costs results in a situation in which future customers must pay part of the cost of present water consumption.

A study made by the author some years ago (*1*) disclosed that municipal plants which charge depreciation allowances in their operating statements use substantially higher percentages than those fixed by commissions for private utilities. The money thus accumulated is generally used for new construction. This procedure is believed to be in the customers' interest.

The significance of fixed charges to private and public ownership differs. The privately operated plant must secure through rates an amount sufficient to earn a fair return upon the fair value of the property; otherwise, it cannot continue to attract capital in competition with other industries. Usually in private operation the state regulatory commissions do not permit more than 60–67 per cent of the capitalization to be in bonds. The earnings in excess of fixed charges are subject to federal income tax at 52 per cent, a charge from which the municipal plant is exempt.

Interest rates on indebtedness of municipal plants are also ordinarily lower because of the fact that income from municipal securities is usually exempt from federal taxation, and frequently from state taxation as well. In many states nothing is paid by municipal utilities in lieu of property taxes which would be paid by privately owned water works.

Both privately and municipally owned water works must earn a substantial surplus beyond the fixed-charge requirements. To make municipal water revenue bonds an attractive investment their annual earnings available for debt service should equal 30–50 per cent more than the annual requirements of interest and amortization. This is also true of the securities of private companies.

Rates Beyond City Limits

In municipal plants, the customers are themselves the stockholders and, as such, entitled to water "at cost"—including in that cost proper provision for financing growth. When all or a part of the investment has been retired from earnings, it is the author's belief that rates within the city limits should include only such fixed charges as are actually paid for interest and amortization on the remaining debt.

Concerning water sold outside the corporate limits, however, it is believed that municipal plants should base rates upon operation as a utility. Such service should yield a reasonable return on the value of the facilities. In a number of cases in which outside rates have been computed at fair return on fair value, the outside customers have been charged at rates 50–75 per cent higher than those within the corporate limits.

Changing Revenue Requirements

No water works is static, even though it serves a community which is experiencing no substantial population growth. Even in such a community, the per capita use of water is increasing, and the standards by which water quality is measured are becoming more exacting with regard to degree of purification, taste and odor requirements, and chemical characteristics.

By the same token, neither are water revenue requirements static. All capital expenditures must be financed, either directly or indirectly, from revenues. The capital investment in water supplies has been undergoing a marked change in the past several decades. About 50 years ago, a Bureau of the Census survey revealed that the book investment in water works at that time averaged about $30 per capita. By 1940 this average had increased to about $75, and at present is probably about $100 per capita. From these figures, it is apparent that book investment in water works has increased, over the last half century, at an average rate of approximately $1.50 per capita per year. Currently, water

works construction costs about $200 per capita.

Because it costs approximately six times as much today to provide water for a new customer as it did 50 years ago, it is apparent that old customers are paying a large share of the new customers' water bill. Unless the regulatory commissions and municipal bodies responsible for the fixing of rates recognize that fair value as well as original cost should be considered in determining equitable rates, water works will be subject to a creeping economic paralysis resulting from the dilution of 100-cent dollars with those of continually decreasing value.

Discriminatory Rates

Under usual rate determinations, new water customers are currently enjoying discriminatory rates. The cost of construction at $200 per capita is $800 per new service. Figuring 6 per cent return and 1.5 per cent for depreciation plus operation and maintenance expenses, the new residential customer's payment of $20–$25 per year will not cover more than a third of his cost to the system. The remainder must be provided from revenues derived from old customers—a clearly discriminatory practice.

State utility commissions partially recognize this inequity in their rules by declaring that new customers requiring extensions of mains must advance that part of the cost in excess of 2.5–4 times their first year's revenue (that is, all costs over $50–$100). As the average service spacing, even in highly developed areas, is about 60 ft, the cost of a 6-in. diameter main is about $210, and the customer therefore advances one-half to three-fourths of the cost. This amount, however, covers only about a fourth of the total investment in facilities from the source of supply to the service pipe required to serve the new customer.

A possible remedy is a connection charge for all new customers. Otherwise, their deflated-dollar annual revenue will not pay their proportionate share of the inflated investment made for them.

Current Reproduction Cost

During the past 25 years construction costs have increased nearly fivefold. This period, however, covers only about a third the life-span of most midwestern water works and a fifth or less of that of many water works in the East.

Records of the costs of very early water works construction indicate that with the crude facilities then available it required about the same investment per service as it did 100 years later, although labor rates had increased materially. In the last 50 years, however, there has been a sharp increase.

Water works abandon very little property: accordingly, it is probable that considerably more than 75 per cent of all expenditures for water works construction made in this country during the past 150 years is still in service. This fact has caused much debate in fixing rates for water works service. Practice varies from exclusive use of current cost of reproduction (less depreciation) to consideration only of original cost in fixing the rate base.

It is the author's opinion that cost of reproduction is at least entitled to major consideration and accordingly his office has made many cost-of-reproduction estimates of water works properties whose original cost is also available. From these studies, made during the past several years of continually increasing prices, it is found that the

current reproduction cost (less depreciation) of water works systems is 1.75–2.5 times the original investment made over a period of several decades. The average of six recent estimates was 1.94. The range depends primarily upon the extent to which the property has been expanded during recent periods of high costs. With some of the older properties, built 25–100 years ago, the ratio will be larger—perhaps as high as 3:1. Among recently constructed properties, however—even though some of them have substantially doubled their investment in the 10 years since the end of World War II—the ratio of current reproduction cost (less depreciation) to original cost was never less than 1.75:1.

Are water works subject to any different economic laws than individuals or corporations?

Are water works receiving adequate remuneration at rates computed upon a base of only half their fair value, when such earnings must necessarily be spent in the open market of inflated prices and deflated dollars?

Is it *dollars* or *facilities* that furnish the service and are exhausted by use?

When commodities, facilities, or structures are traded in at sufficiently frequent intervals to establish "market value," the trading prices reflect the current purchasing value of the dollar. Unfortunately, water works are rarely bought and sold, and in order to secure a measure of their present value, estimates of reproduction cost (less depreciation) at current price levels are made. Some regulatory commissions give little weight to such estimates. Probably few water works would contend for immediate adjustment of rates to reflect fully the current cost of reproduction. It is interesting to note, however, that in cases where a city acquires the water works property it almost invariably pays a price based largely or entirely upon cost-of-reproduction estimates—even though it may have argued for original cost as a basis for rates for the private company.

If water works facilities were as short-lived as telephone or electric power facilities, the difference would not be so great, but with two-thirds of water works value in the long-life distribution system, and an overall system life as much as ten times that of some other utilities, the water works industry must have consideration from the fair value viewpoint if it is to meet its requirements satisfactorily.

TABLE 1

Growth of American Economy Since World War II

Item	Prewar	1955	Increase *per cent*
Population—*millions*	133.8	166.5*	25
Personal incomes—*billion dollars*	102	315	210
Cost of living†	65.9	114.7	74
Hourly factory wages—*dollars*	0.66	1.93	192
Wholesale prices†	66.9	112	68
ENR Construction Cost Index‡	235.5	680	188
Water rates	—	—	0–75

* 1955 population estimated.
† 1947 = 100.
‡ *Eng. News-Record* (Dec. 1955).

The figures in Table 1, derived from *The Magazine of Wall Street* illustrate changes in the American economy since the beginning of World War II.

Operation and Maintenance Costs

Every water works has been experiencing a rapid increase in the cost of operation and maintenance, particularly in the last 10 years. Table 2 shows

the reported increase of plants in several cities. From this table it will be noted that in the 9 years following World War II operation and maintenance expenses per unit output have substantially doubled. Because operation and maintenance expenses represent from 50 to 70 per cent of the total cost of operating most water works properties, it is apparent that rates which were adequate 10 years ago are no longer sufficient.

Comparison was made of the *ENR* (*Engineering News-Record*) Construction Cost Index with the records of Chicago, Louisville, and Des Moines for operation and maintenance expenditures per million gallons for the period 1945–54. Although the increases for the individual cities varied, a plot of the average increase of all three generally followed the *ENR* increase curve, but was about 10 per cent lower.

Inasmuch as operation and maintenance costs have substantially doubled in recent years and require 50–70 per cent of water works revenue, it is apparent that to compensate for this element alone a 25–35 per cent increase in revenue per million gallons would be necessary in this period merely to maintain the position of 1945.

Capital Additions

In the 25-year period prior to 1945 the water works industry was expending $7.35 per customer (or about $1.75 per capita) per year from earnings to finance new construction. This was about 25 per cent of the gross revenue. Assuming no change in rate of growth, this expenditure would now—as a result of rising costs—be at least $18–$20 per customer, an increase of about $12 per customer over 1945. This $12 is equal to 37.5 per cent of the 1945 average revenue per customer. Many water works have increased rates since 1945, of course, and this $12 per customer increase would probably be equivalent to about 25 per cent of current average revenue. Capital improvements must be made. Inasmuch as financing from current revenue is usually about 40 per cent less costly than financing from funded debt, it is obvious that revenues should be sufficient to finance as much new construction as possible from earnings.

In 1945 the average water works had $7.50 per customer left from earnings each year to cover fixed charges, return, and similar items. Even assuming that this amount is adequate for 1956 it is apparent from the foregoing that 1945 water revenues would have to be increased 25–35 per cent for higher operation and maintenance costs plus about 37.5 per cent more to maintain construction progress—or a total of 65–70 per cent, as a general average.

Many water works have had substantial rate increases. Some private companies have had two—and a limited few, three—increases, but there are still many water works trying to main-

TABLE 2

Increase in Operation and Maintenance Costs, 1945–54

Plant	Ownership*	Cost Increase *per cent 1945 avg*
A	M	202
B	M	180
C	M	178
D	P	169
E	P	168
F†	M	130
G†	M	132
Avg Plants A–E		180

* Municipal plants designated M; privately owned, P.
† Gravity supply.

tain service at pre–World War II rates. In general this is impossible, and to attempt it is usually unwise; almost without exception it results in inadequate service, dissatisfied customers, and the overlong deferral of necessary plant expansion. Within recent years practically all important water works construction programs, whether public or private, have required increased revenue before they could be economically financed.

From a rather inadequate sampling of plants for which data were readily available to the author it would appear that the average annual revenue per customer has risen from $32.10 (the average of 100 plants studied in 1945) to $50–$60 per year in 1955. The 1955 per capita revenue is probably about $12.50 per year.

In three recent rate cases involving private water companies in three different midwestern states the regulatory commissions' decisions resulted in gross revenues of $65.33, $87.07, and $65.50 per customer. In 1945 these three companies had gross revenues per customer of $38.47, $42.30, and $32.40, respectively. The average of the increases for the three companies in the 10-year period was 93 per cent. These companies have the advantage of alert management responsive to the need of maintaining earnings sufficient to attract the capital necessary for their rapid growth. Their per customer revenues and their 10-year increases are probably materially greater than the national averages—but no doubt reflect fairly well what those averages should be.

Forecasting Needs

It is just as essential for a water works to study its requirements and provide for them in advance of their maturity as it is for an individual to plan ahead. This is particularly true in areas of rapid growth.

Every water works should periodically have its needs projected into the future for at least two decades: the required new construction outlined, construction costs estimated, and the impact of those costs (along with changes in operating procedures) on the total annual expenses estimated. Construction expenditures should be coordinated with revenues as far as possible, and rates should be charged as needed to maintain high service standards.

Water is cheap, and experience has usually shown that the people will vote the necessary bonds or approve rate increases when they are convinced of the necessity. Unless they are so convinced, however, they may vote otherwise, as is illustrated by the experience of Denver, Colo. The voters of that city defeated a $20,000,000 bond issue and a year later—after a comprehensive survey and report and an effective educational campaign—approved a $75,000,000 issue by a 14-to-1 margin.

Electric Utilities

Analysis of the operation statistics of five electric companies in four midwestern states serving about 1,500,000 customers discloses revenues from residential customers varying from $70.65 to $83.06 per year, and averaging $77.96 per year. This is at least three times as great as the average residential water bill in the same area. These electric companies have grown so rapidly that the average dollar age of their investment is less than 10 years (about a third that of the average water works) and their revenues are 2.6 times as much as they were 10 years ago. There would appear to be little reason why consumers would not be

willing to pay as much for water as for electric service, if they were convinced of the necessity. Possibly one element in this situation is the fact that 80 per cent of water works are publicly owned, and politicians are more allergic to rate increases than are stockholders.

Conclusions

From the foregoing, combined with the author's own extensive experience in presenting revenue requirements of water works before city agencies and regulatory commissions, the following conclusions are offered:

1. Water rates in general are too low. More adequate revenues would be in the interest of both the water supplier and the water user.

2. As a general statement it is believed that, under conditions now prevailing, a minimum charge of less than $1.50 per month, permitting the use of 2,000 gal of water per month, cannot be equitably sustained for most water works. As an indication of the reasonableness of this statement, regulatory commissions in three midwestern states have recently fixed minimum charges for ⅝-in. meters for major water utilities of $2.22, $2.60, and $2.83 per month, respectively.

3. Since half of all residential consumers in nearly all cities use less than 3,000 gal per month, the amount of water furnished under the minimum rate should be reduced to not more than 2,000 gal per month. A 3,000-gal per month allowance offers no incentive for water conservation to nearly half of the residential consumers.

4. The public wants adequate water service. The average domestic service throughout the country uses about 6,000 gal per month, for which the customer currently pays $20–$25 per year. An increase of about one cent per capita per day would increase the residential revenue more than 50 per cent. Corresponding percentage increases in industrial and commercial rates would produce sufficient revenues for most plants. This seems a small price to pay for the difference between good and mediocre—or even unsatisfactory—service.

5. Good water service requires good management. Good management studies water requirements in advance, provides for meeting expanding needs before they mature, coordinates construction and financial programs, acquaints the public with financial requirements for good service, and provides the facilities before an actual emergency develops.

6. Adequate revenues today are the best assurance of satisfactory water works service tomorrow.

Reference

1. Howson, Louis R. Dollars and Sense of Depreciation. *Jour. AWWA*, **36**:803 (Aug. 1944).

Development of Private Utility Companies in Florida

John W. Greenleaf Jr.

A paper presented on Nov. 9, 1955, at the Florida Section Meeting, Orlando, Fla., by John W. Greenleaf Jr., Partner, Rader Eng. Co., Miami, Fla.

PRIVATE utility companies may be defined as those which have been created for the specific purpose of serving subdivision developments with water, sewerage facilities, and even gas, and which, generally, have been constructed concurrently with the subdivision development. These private utility companies have usually been created to provide services beyond the reach of the presently established municipal systems and, in most cases, such systems have been constructed only after failure in obtaining service from the existing utilities of the nearest municipalities.

Background

An examination of State Board of Health records for Florida gives mute evidence of the growth of the private utility companies in providing sanitary service for subdivision developments in the state. These records show that, since 1950, applications have been filed for 200 water systems, of which 150 have been for private utility companies. Sixty-five applications have been filed by private utility companies since 1950 for sewerage systems, which will ultimately serve a total of over 258,000 people. Table 1 shows the total number of annual applications for water and sewerage systems made to the Florida State Board of Health by private utility companies. The growth of the private utility company has been one of gradual evolution, and it was not until 1953 that the private company began to play a major role as a provider of sanitary-sewerage facilities.

In the beginning, the private utility company was created by real estate housing developers to serve as a parent for utility systems which had been constructed for housing projects and for which there was no community or municipality to take over operation and maintenance. Although the private utility company may be the creation of the real estate developer, however, he has little or no interest in the construction and operation of utilities; it is a field with which he is relatively unacquainted, and he would prefer to devote his capital and efforts elsewhere. Occasionally, utility systems have been installed and put into operation by the real estate developer and then, upon the sale of the last house in the development, the system has been abandoned to an uncertain future. To prevent this and to be certain that utility systems have the proper care and guidance, both the Federal Housing Administration and the Veterans Administration have required the establishment of trust deeds, which assure the continued own-

ership of the utility and guarantee its operation on all projects for which the administrations have insured loans. The execution of such a trust agreement by the developer of the utility system is now required, and no final commitment can be made on a house to be constructed under a federally insured program until the construction of the utility systems has been completed and is certified to be in accordance with approved plans.

TABLE 1

Annual Applications for Private Water and Sewerage Systems

Year	Water Systems	Sewage Plants	Population Designed For	
			Immediate	Ultimate
1950	20	3	2,500	6,026
1951	12	5	4,130	8,476
1952	20	6	3,858	8,708
1953	24	12	8,001	47,327
1954	32	21	18,194	93,809
1955	42*	18*	11,523	93,785
Total	150	65	48,205	258,131

* Data are for 9 months only.

Financing

Both the Federal Housing Administration and the Veterans Administration recognize the increase in value of property brought about by the installation of water and sanitary-sewerage systems. Although the exact increase in the value of a lot is dependent upon a number of variables, an increase of $150 has frequently been allowed by these agencies for the average-sized lot served from a community water system, and $250 is an average increase in the value of a similar lot where sanitary sewers have been installed.

This increase in the reasonable value of the property resulting from the installation of utilities has made it possible to attract the capital necessary for the construction of these utility systems. It has also established a pattern under which the housing developer pays to the utility company a connection fee generally approximating the increase in reasonable value assigned to utility construction. This capital, unlike that of the housing builder, has to do with the long-term capital-gains aspect of the investment rather than with quick turnover. Like the builder's capital, however, it must definitely be considered risk capital because the utility operator must invest the funds required to provide the necessary services for the buildings being constructed and to have these services ready at the time the buildings are completed and put up for sale. Until the builder's houses are sold and occupied there are no customers for the utility systems and, therefore, no income. Because the rate at which the customers are added to the utility system depends entirely upon the construction and sale of buildings, the time required to develop sufficient customers necessary for a self-sustaining utility system is completely unpredictable. Similarly, the period of time required to develop a return on the invested capital is unpredictable, as is the rate of return which may be developed. In view of these uncertainties, this type of venture capital demands and is entitled to a considerably larger rate of return than is normally considered equitable for more stable investments.

This is a completely different concept of financing from that usually considered in the field of sanitary-sewerage construction, where general obligation bonds of a municipality or taxing district, or revenue bonds of an established utility are frequently issued.

Such bonds are usually tax free and enjoy a low rate of interest, the exact rate depending upon the history and reputation of the community involved. Also, the financing of a private utility company constructed to serve a subdivision is a different concept from the financing of a private utility company operating under a franchise within an established community. Most such utility companies have entered into franchise agreements with established communities, where a number of customers could be assured at the outset and the returns on the investment could be calculated in advance with a reasonable degree of accuracy. This type of investment has long been considered conservative and the desirability of the particular investment is dependent largely upon the management policies of the company involved and upon the general economic possibilities and probabilities which the area served can offer.

Over the past several years, the author has devoted much of his time to engineering work related to the planning, design, and supervision of constructing private utility systems serving subdivisions, particularly those located in the south of Florida.

Probably the outstanding difference between the design problems in normal municipal work and those found in the design of private utility systems serving subdivisions is one of economics. Each private utility development, either through direct or indirect revenues, must be able to meet its operation and maintenance costs if it is to continue providing the necessary service. Furthermore, in order to attract the capital necessary for the construction of such utilities, operating revenues must, within a reasonable period, be sufficient to pay a return on the invested capital commensurate with the risk involved. Payment of operating and maintenance costs, insurance, taxes, depreciation, and other costs, as well as the necessary return on the investment, must all come from operating revenues. These revenues are dependent on rates charged for the service provided, which, in turn, are predicated upon the rates charged by municipalities in nearby areas. Such municipal rates are frequently based on utility systems installed during periods of lower construction costs and on the lower interest rates of the tax-exempt municipal securities.

Economic considerations limit the minimum size of utility systems which can be built and operated independently. They also frequently limit the extent and type of treatment which can be provided, particularly in the smaller installations. It is for economic reasons that a utility must be designed and developed to employ a minimum of personnel for operation, and the capital cost of construction of the utility systems must be consistent with economic operation and maintenance.

Provisions for Future

One of the most serious problems facing the engineer and developer of subdivision utility systems is that of determining the probable rate of growth of the subdivision and of providing utility systems which will function economically and properly at each stage of the subdivision development. The answer to this problem has frequently been found in stage development and construction, where ultimate plant capacity required for either water or sewage treatment has been provided by two or more units, with only one of these

units being constructed under the initial development.

By this method, water and sewage treatment plants have been initially designed and constructed for, say, 3,500 people, or 1,000 homes, and subsequently expanded to provide a capacity for 2,000 or 3,000 homes as building progresses in the area. The construction of the water distribution and sewage collection systems is usually scheduled to closely follow the building construction program, thus ensuring not only that the services will be ready when required, but that the services will be used and that a return will be forthcoming on the invested capital within a minimum period of time. Although the development of treatment facilities under a program of stage construction results in a somewhat greater total capital outlay than would initial construction of a single plant to the ultimate capacity, such a program of stage construction limits the initial investment required and permits a greater return on the invested capital during the development period of the area served by the utilities. The decision as to which construction method is preferable is usually dependent upon estimates of the rate of growth to be expected within the area served. Frequently, however, limitations on the amount of capital available are the deciding factors and, in many cases, temporary or interim facilities are installed even before the first full stage of construction is undertaken.

Because of the many possible methods of approaching this problem and because of differences in the facilities required, a great deal of care must be used in the analysis and interpretation of cost data covering any proposed private utility system. The costs reported by seven different private utility companies presently operating water and sewerage systems in the south of Florida are shown in Table 2.

It will be noted that the minimum investment per lot is $562.86, and the maximum investment per lot is $1,393.47, with an average cost of $830.00 per lot based on construction for 4,682 lots and a total cost of $3,880,000. Contributions from builders to these utility companies vary from a minimum of $350.00 to a maximum of $500.00 and Federal Housing Administration and Veterans Administration increases in reasonable value, for the companies reporting, show a variation of from $300.00 to $475.00 per lot. The portion of total cost represented by the builders' contribution varies from a minimum of 35.8 per cent to a maximum of 69.3 per cent, averaging 54 per cent for all of the utility companies involved. It is of interest to note that the lowest percentage is for the highest contribution, and the next to the highest percentage is for the lowest contribution. It should be pointed out that the costs as shown by this table include such items as land, legal, engineering, administration, interest, and other costs which are frequently overlooked in the preparation of preliminary estimates but which are a real and substantial part of the investment that must be made by the utility company.

Space Limitations

Another problem facing the engineer on the subdivision utility design is the limited space usually available for the construction of the water supply and sewage treatment facilities. The cost of land on any successful subdivision is high. The developer of a subdivision

TABLE 2

Costs Reported by Seven Private Utilities

Item	Costs Reported—$*						
	Utility *A*	Utility *B*	Utility *C*	Utility *D*	Utility *E*	Utility *F*	Utility *G*
Total investment	1,088,000.	1,062,960.	609,000.	432,600.	378,000.	292,868.	224,500.
Actual water customers	700	420	200	656	125	12	125
Actual sewerage customers	600	420	200	294	125	12	100
Presently constructed capacity for water	1,320	1,042	918	767	380	210	345
Potential customers	12,000	3,000	4,000			4,000	600
Water							
Distribution cost per customer	178.57	187.00	164.00	141.43	226.67	239.99	81.18
Supply cost per customer	245.00	87.00	86.50	49.34	52.00	291.51	141.67
Total cost per customer	423.57	274.00	250.50	190.77	278.67	531.50	222.85
Sewerage							
Collection cost per customer	221.43	468.50	290.00	240.29	340.00	305.20	220.00
Pumping cost per customer	33.33	22.70	37.00	58.99	134.44	64.36	38.33
Treatment cost per customer	145.00	254.20	86.00	72.81	244.00	492.41	168.33
Total cost per customer	399.76	745.40	413.00	372.09	718.44	861.97	426.66
Contribution from builder	400.00	475.00	375.00	350.00	500.00	500.00	450.00
Percentage of cost	48.5%	46.7%	58.5%	62.3%	50.1%	35.8%	69.3%
Total cost of water & sewer systems	823.33	1,019.40	663.50	562.86	997.11	1,393.47	649.51
FHA or VA allowance		475.00			300.00	325.00	
	Type of Facility						
Water							
Wells	x	x	x	x	x	x	x
Aeration						x	
Ground storage						x	
Hydro-pneumatic storage		x	x	x	x	x	x
Elevated storage	x						
Softening	x		x				
Sewerage							
Imhoff tank				x	x		x
Trickling filter			x				x
Sand filters				x	x	x	
Primary settling	x	x	x				
Secondary settling	x	x	x				x
Activated sludge	x	x					
Separate sludge digester	x	x	x				
Chlorine contact tank	x	x	x				x
Septic tank						x	

* Unless otherwise noted.

usually owns a limited area and it is frequently difficult or impossible to obtain land outside of this area for utility purposes, particularly for the construction of sewage treatment facilities. This means that sewage treatment plants must generally be constructed within the proposed urban area, in close proximity to commercial or residential properties. The size of the tracts available for the construction of these plants is limited and the designer must provide a plant which will be harmonious with its surroundings and which will not be objectionable to those living in close proximity, either through its appearance or because of odors.

In this connection, the odor problems frequently encountered by operators of new sewage treatment plants in urban areas should be mentioned. Since the subdivision sewage treatment plants are required to start operation as soon

as the first residence in the subdivision is occupied, these plants are usually required to operate for long periods at capacities considerably below those provided for in the plant design. Similarly, sewage collecting systems, force mains, and other parts of the system are operated at capacities which are far below their designed capacity. This results in low velocities in the sewerage system and excessive detention times in the various parts of the treatment plant, so that septic sewage and its attendant odors has been a serious problem for many of the operators until such time as the system is reasonably loaded. This problem presents a challenge not only to the plant operators, but also to the designing engineer.

The rapid development of the private utility company serving subdivisions has been greeted with mixed feelings by governmental officials and the public. Everyone is in favor of providing safe water supplies and sanitary-sewerage systems to the new homes under construction in suburban areas, but, as more and more private utility systems serving subdivisions are constructed with individual sewage treatment plants, there is increasing apprehension that this may not be the answer to the problem. Such doubts are strengthened by every case where a privately owned water supply or sewage system is not giving completely satisfactory service or is even creating a nuisance in its vicinity. It is therefore particularly important that the engineer, owner, and operator take all steps required to ensure first-class service to the consuming public and to eliminate any possible cause for criticism. The engineer is further charged with the responsibility of designing a distribution and collection system of these utilities in such a manner that they may one day be incorporated in an overall system operated by the municipality or by a metropolitan district.

It is particularly important that private utility systems, at the time of their establishment, be required to define the area within which the company will provide service and establish the charges, contributions, and conditions under which such services will be furnished. In this manner, both the owner of the utility service and his investment can be protected by the establishment of regulations which prevent competition within the prescribed area and, at the same time, the builder or developer within this area will be protected by knowing in advance what charges and fees will be made for these services and under what conditions they will be provided.

A step in the right direction might be the requirement that a franchise be granted by the county or other local government as a condition for permitting construction and operation. The owners and operators of the utilities would welcome such a step because it would provide a definite legal recognition at the local level and establish rights for operation over a definite period. It would also define the steps and conditions under which the utility could be taken over by a public agency. The granting of a franchise could not only establish whatever controls may appear desirable but could also ensure that, between various utility companies, whole areas would be served with the utilities necessary to permit their orderly development. In this way the problem of developing independent utility systems to serve small areas, where economic operations are not possible, could be avoided. Also, the num-

ber of sewage treatment plants required could be maintained within reasonable limits and, possibly, sites could be designated for this use so as to fit into the overall planning of the entire area. Such franchises could require that the individual systems be constructed so that, at a later date, they would form a part of an area-wide program with a minimum of loss of investment. The granting of such franchises would have the approval of the Federal Housing and Veterans Administrations and would avoid the necessity of invoking the provisions of Regulation 1500 of FHA.*

Public officials in each of these rapidly developing urban areas, where large-scale subdivisions are under construction, must start to plan for the eventual integration of the individual subdivision utility systems into an overall district. To this end, engineering studies should be undertaken and master plans should be prepared by which the construction of the individual utility systems can be guided so as to ensure the greatest possible use of such systems when the overall district is developed.

Conclusions

There is no need for apprehension regarding the construction of the private subdivision utility systems if the public official is awake to the opportunities and responsiblities associated with this development. If he will carry out the necessary engineering studies required to provide a program for future development and if he will control the development of such utility systems through the issuance of franchises, then development by the private utility company of water distribution and sewage collection systems, with their paying customers and established revenues, will provide the means whereby financing can be obtained and integration of the private systems can be accomplished by a single large program of financing and construction or by a progressive program, according to the particular needs.

The private subdivision utility company is today fulfilling a definite need in the rapidly expanding economy of Florida, and is providing a much-needed service in the safeguard of public health.

* This regulation required that the trust deeds under which private utilities are constructed contain the provision that subdivision utilities could only be transferred to a governmental authority or public utility, and that any consideration accruing from such sale or transfer was to be distributed among the property owners served by the system. This regulation has since been voided.

Analysis of Seasonal Water Consumption in Danville, Ill.

Keith A. Yarborough

A contribution to the Journal by Keith A. Yarborough, Graduate Student, Dept. of San. Eng., Univ. of Illinois, Urbana, Ill.

EFFECTIVE utilization of water supply resources is dependent upon an understanding of comparative seasonal consumption. This is true of systems utilizing both surface and ground supplies. There has been considerable discussion in recent literature concerning the relative effects of air conditioning, lawn sprinkling, and similar demands on peak summer flows. Many municipalities have reported that serious water shortages during the summer months have often necessitated restrictive policies as to water use.

Danville, Illinois

A study has been made of seasonal consumption in Danville, Ill., to provide some quantitative information concerning recent water demands of such a medium-sized city. Danville has a population of about 40,000 and is located in the extreme east central portion of the state. It is surrounded by rich farmlands and is also the site of several industries, including a foundry, three chemical companies, an artificial-ice plant, a food-packing concern, and an electrical-manufacturing company. As a result of the current program of nationwide industrial decentralization, additional industries are moving into the region, which is served by three major railroads.

Water is supplied to about 50,000 persons in the city and environs by the Inter-State Water Company, a privately owned and operated concern. The source of supply is Lake Vermillion, a reservoir created by damming the north fork of the Vermillion River. Treatment consists of chemical coagulation, settling, filtration, and chlorination.

Background

Danville was selected for this study because of its size and the availability of complete and carefully maintained records. The city is large enough to present the desired sampling of zones having completely metered services and is, at the same time, small enough to exclude the complications of a large city. Of great importance was the willingness of the private utility to permit the selection of pertinent data from its records.

Although the water company has not yet felt a really serious pinch from increased demands, it has noted a general rise in its water output. This was especially true of the summer months of the last few years.

The period 1950–55 was chosen for study because water works operators reported an extended shortage in Illinois during that period. Data were taken from the company's house meter records for the summer quarter (Jun. 15–Sep. 15) and the winter quarter (Dec. 15–Mar. 15) because these periods were believed to reflect the maxi-

mum in differential consumption. The records are kept to the nearest 100 cu feet for each quarter.

To give further meaning to the data, water consumption information was obtained for five different zones in the city. These zones were selected on the basis of their respective property evaluations. Table 1 presents summarized data for the several zones.

Because all dwellings in the five zones were two stories or less, no attempt was made to distinguish between the types of dwellings and only the overall lot area was considered. This seemed the best method of accounting for the portion of total individual consumption attributable to uses within the dwelling. So that the areas of the five zones could be seen more clearly in relation to each other, an "area factor" was used. With the area of Zone *A* as the "base area," areas of the other zones were converted to equivalent areas. Thus, the area factor for a Zone *X* would be $\frac{\text{area of Zone } A}{\text{area of Zone } X}$.

Assessed-property evaluation was used as the basis of selection because it was felt to be more truly representative of the class of people living in a zone than average annual income would have been. Assessed property reflects not only the type and size of the dwelling, but also the care with which it and the surrounding yard are maintained. It is, therefore, a better reflection of the overall water consumption activities of the person living in that dwelling.

Assessed-property evaluation was also felt to be more representative of *relative* water consumption. If two men of similar natures have the same annual incomes, for instance, and one lives in an apartment house while the other lives in a one-family dwelling unit with a yard, the latter probably would use more water to maintain his property. The assessed-property evaluation of the dwellings of each of these men is a better measure of consumption than is their annual income, and the evaluation of each particular zone is much more likely to remain constant over a period such as the one selected for this study.

TABLE 1

Data on Consumption in Five Zones

Zone	Number of Residences*	Average Assessed Property Evaluation $	Total Area *1,000,000 sq ft*	Area Factor
A	38	15,270	1.50	1
B	37	12,210	1.06	1.42
C	86	6,070	0.66	2.28
D	82	3,200	0.57	2.64
E	41	2,280	0.53	2.83

* All residences are one-family dwelling units.

Results

Table 2 presents the summarized information obtained from the study. As might be expected, the summer consumption was always greater than the winter consumption, with the exception of the 1950 consumption in Zone *E*. In Fig. 1, assessed-property

evaluation is plotted against total water consumption for the 6-year period, and the results shown are rather surprising. The curves indicate that water use is not a direct function of property evaluation. In fact, it is not the areas of higher evaluation which have the greatest summer and winter usages, but the areas of upper-middle-class residences. One might expect the converse to be true—that is, that the assessed evaluation decreased. Although, as an individual, the consumer in Zone *C* uses less water than does the consumer of Zone *A*, the *total* consumption in Zone *C* is greater than that in Zone *A* because there is a greater density of residences in Zone *C*. On the basis of respective property evaluation, then, there is a range of evaluations in which the number of dwellings per unit area becomes critical. In this range, the overall consumption of the occupants of the zone can far outweigh the consumption of the same-size zone of higher- or lower-assessed property evaluation.

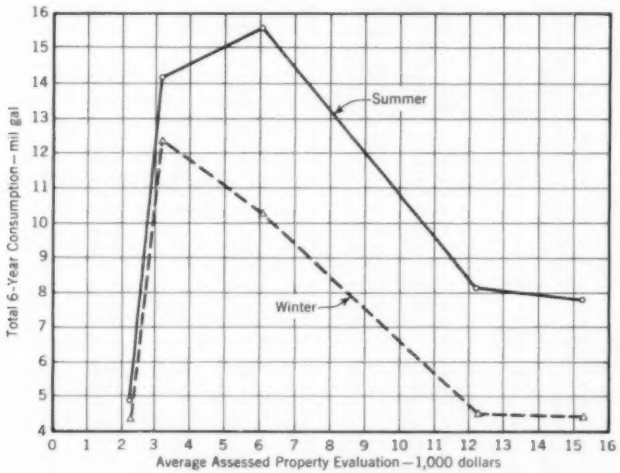

Fig. 1. Relation Between Seasonal Consumption and Assessed-Property Evaluation

As the curves indicate, water use is not a direct function of property evaluation. The areas of greatest summer and winter usages occur in the upper-middle-class zones.

greater the evaluation of the property, the greater would be the respective water consumption.

An explanation of this seems very important. As has been mentioned, the consumption in each area was weighted by use of the area factor. As Table 2 indicates, the people in Zone *A* used more water *per residence* than did those living in the other zones—the usage per residence decreasing as the

In designing a water distribution system for a particular area, the engineer should not only know the expected population for the design period, but he must have some idea of the type of people who will be living in that area.

TABLE 2

Consumption, Precipitation, and Climatological Data for Danville, Ill.—1950–55

Year	Quarter	Total Seasonal Consumption in Zones of Equivalent Area—*mil gal*					Per Residence Consumption in Zones of Equivalent Area—*mil gal*					Avg Seasonal Climatological Data		
		A	*B*	*C*	*D*	*E*	*A*	*B*	*C*	*D*	*E*	Precipitation *in.*	Temperature °*F*	Evaporation* *in.*
1950	Winter	0.63	0.69	1.72	2.04	0.74	0.017	0.013	0.009	0.009	0.006	4.35	34.9	
	Summer	0.85	0.78	2.16	2.21	0.72	0.022	0.015	0.011	0.010	0.006	4.48	69.8	4.04
1951	Winter	0.64	0.63	1.82	2.12	0.68	0.017	0.012	0.009	0.010	0.006	3.16	30.1	
	Summer	0.92	0.93	2.22	2.28	0.69	0.024	0.018	0.011	0.011	0.006	4.04	69.6	4.59
1952	Winter	0.70	0.71	1.67	2.03	0.68	0.018	0.014	0.009	0.009	0.006	2.40	34.0	
	Summer	1.11	1.37	2.34	2.29	0.92	0.029	0.026	0.012	0.011	0.008	3.43	73.4	5.78
1953	Winter	0.80	0.83	1.72	2.01	0.58	0.021	0.016	0.009	0.009	0.005	2.68	26.9	
	Summer	1.50	1.89	2.82	2.38	0.70	0.039	0.036	0.014	0.011	0.006	2.41	73.1	7.64
1954	Winter	0.77	0.83	1.69	2.11	0.98	0.020	0.016	0.009	0.010	0.008	1.66	35.4	
	Summer	1.77	1.70	3.02	2.52	0.98	0.047	0.032	0.015	0.012	0.008	2.80	74.5	6.49
1955	Winter	0.91	0.83	1.66	2.10	0.73	0.024	0.016	0.008	0.010	0.006	1.96	33.1	
	Summer	1.65	1.46	2.98	2.52	0.88	0.043	0.028	0.015	0.012	0.008	2.77	71.2	6.24
6-year total	Winter	4.44	4.52	10.28	12.40	4.40	0.117	0.086	0.052	0.057	0.038			
	Summer	7.80	8.13	15.53	14.20	4.90	0.205	0.155	0.079	0.066	0.042			

* Evaporation is not recorded in the winter.

Their respective activities will determine water consumption.

The use of relative areas is very realistic from the standpoint of design. Knowing the estimated assessed-property evaluation of dwellings to be constructed in a zone, the designer can plan for the total supply of all these dwellings. This information is far more important to him than are consumption data for individual services.

To provide direct checks on the above findings and furnish other information of interest, a door-to-door survey was made of ten homes in each of the zones. These were selected on the basis of their consistently higher-than-average consumption for that zone. The findings of this survey were such as to preclude tabulation and permit only general comment.

The most important observation made from these rather limited area samples was that, in the five zones selected, the increased consumption during the summer resulted primarily from lawn sprinkling. Little or none of this consumption was attributable to air-conditioning requirements. (In the five zones, only one house was found to have a liquid-cooled air-conditioning unit.) The other uses remained about the same during both the summer and winter quarters, except for baths and showers. It was also found that the increased demands occurred despite the fact that many families in the zones took vacations in the summer.

Climatological Data

The last part of the study was an attempt to correlate the summer and winter demands with climatological data. This provides a means of explaining the consistently greater consumption during the summer. Figure 2, which was prepared from the cli-

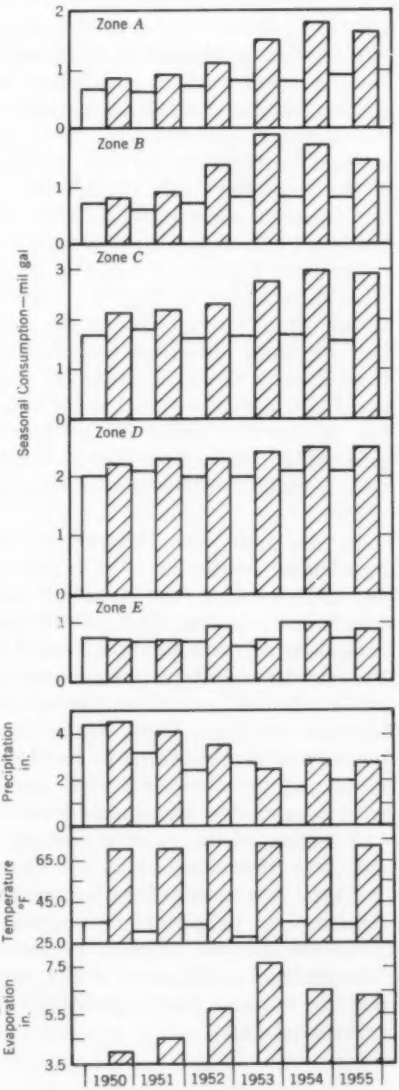

Fig. 2. Seasonal Consumption and Climatological Conditions

White bars indicate winter; cross-hatched bars, summer.

matological data for the state of Illinois (*1*), shows a plot of the water consumption in each of the five zones for the years studied. Included are graphs for the average temperature, the average precipitation, and the average evaporation for the quarters of the respective years considered.

A general correlation between the combined climatological conditions and the relative demand for water in Zones *A–D* is indicated by Fig. 2. Zone *E* shows erratic variations with the summer demands differing only slightly from those of the winter quarter. Figure 2 also demonstrates that the water use in the five zones is not greatly affected by the climatological conditions prevalent in the area during the winter.

In designing, consideration of climatological conditions is as important as understanding the type of area which is to be supplied. Peak consumption estimates should be based on the relative severity of the climatological conditions prevalent during the summer months. Thus, winter flows might well be considered to be "base" flows and the summer period can be used to estimate maximum demands.

Selection of the most important of the three climatological factors shown in Fig. 2 is a matter of conjecture, and quantitative judgment is impossible from the amount of data presented. The findings of this part of the study must be left on a purely qualitative observational basis.

Conclusions

The study described here has been carried out on a rather limited basis and the information given here should be interpreted with that in mind. The results do illustrate a basic design concept, however, and the designer must evaluate the type of zone with which he will be dealing and from this determine the water consumption for the entire zone without dealing entirely with individual consumption. The study also demonstrates that summer demands are related to the climatological conditions of the region considered.

Acknowledgments

The author wishes to thank Arthur F. Ell, manager of the Inter-State Water Company of Danville, Ill., for his cooperation in making available the basic information from his records and for his aid during the preparation of this paper.

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Reference

1. *Annual Summary of Climatological Data for Illinois.* Vol. 54–60. Weather Bureau, US Dept. of Commerce, Asheville, N.C. (1950–55).

Pipelines Through Easements

Burton S. Grant

A paper presented on Jun. 16, 1955, at the Annual Conference, Chicago, Ill., by Burton S. Grant, Chief Engr. of Water Works and Asst. Mgr., Dept. of Water and Power, Los Angeles, Calif.

PROBABLY the most common reason for locating pipelines on easements, rather than on public thoroughfares, is the necessity of providing the shortest route to the ultimate destination. Other reasons include: [1] the absence of public thoroughfares; [2] lack of permission or franchise to use a public thoroughfare; [3] the obvious disadvantages connected with the occupancy of public thoroughfares; and [4] considerations peculiar to the individual pipeline owner's operations—most often the important matter of economy. In illustration of this last consideration, a situation common in the Los Angeles area provides a good example. The public thoroughfares in hilly terrain are often winding, dead-end streets, on which pipelines require long switchbacks because of the grades involved; a tie line through an easement, however, may be used to reduce the size of mains and to provide more reliable two-way service. Figure 1 shows a typical situation of this kind. The street system shown is a loop 4,870 ft in length, which returns at one point to within 200 ft of itself. Construction of mains only along the public thoroughfare would require 4,030 ft of 12-in. pipe and 840 ft of 8-in. pipe to provide sufficient volumes along the circuit for domestic use and fire flow requirements. The specifications on the diagram indicate the pronounced effect of a 200-ft tie line through an easement at the point of closest proximity. Only 1,100 ft of 8-in. pipe and 3,970 ft of 6-in. pipe are required to render the same service, reducing the cost of the installation almost 50 per cent.

An excellent illustration of the comparative advantages and disadvantages of locating pipelines on easements and on public thoroughfares is provided in the following situation. A major water trunk line is being planned through an area in which a main public thoroughfare is to be constructed. Because the terrain is quite irregular, many cuts and fills will be required to grade the roadway. The first problem confronting the pipeline owner is whether it is preferable to take an easement adjoining the site of the proposed thoroughfare and lay the pipe over the irregular contours of the terrain, or to await the grading of the thoroughfare. (This, of course, assumes that construction of the pipeline can be delayed until the grading is completed.) If the pipe is to be laid on an easement alongside the thoroughfare, a number of problems become immediately apparent. Figure 2 is a profile indicating the irregular grades that the pipe would have to follow if laid on the easement. The grade of the proposed street is also shown on this profile, illustrating clearly the difference between the two alternatives.

The high cuts and fills resulting from the construction of the thoroughfare would create a number of problems, if the pipe were laid on an easement. Access roads would be necessary for maintenance and operation. The presence of such an easement before property fronting on the new street would be

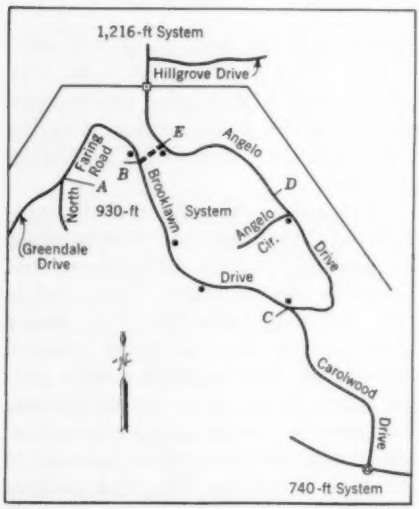

Fig. 1. Tie Line Through Easement
The location of the tie line is indicated by broken lines between points B *and* E. *Without the tie line, main requirements would be 4,030 ft of 12-in. pipe for distance* A-B-C-D *and 840 ft of 8-in. pipe for distance* D-E. *By means of the tie line, the necessary volumes can be delivered using 900 ft of 8-in. pipe for distance* A-B, *3,970 ft of 6-in. pipe for circuit* B-C-D-E, *and 200 ft of 8-in. pipe for the tie line.* ● *represents fire hydrant.*

the cause of continual difficulty for the pipeline owner—future property owners would invariably be seeking undisturbed access to the street and would be the source of frequent complaints about the existence of the line and the necessary access roads. Encroachments upon the easement and over the pipeline could be deliberately planned by the property owners to force relocation of the line. In the valleys, the property owners would desire to place fills to the street level to improve their property access and frontage; similarly, owners on the hill portions would want to excavate their frontage to street level.

Finally, lateral branches from the trunk line might be required at a future date. Installing the laterals from the top of a high cut or the bottom of a fill would involve considerable extra cost and cause recurrent problems with backfill on steep slopes.

Desirable Features

Whether all the desirable characteristics of an easement can be obtained often depends upon the permissible cost of the project. Such characteristics include: adequate width; exclusive rights (especially surface rights); no fencing requirement; slope rights for cuts and fills; temporary construction space; permanent road rights; protection against future relocation of pipeline; and protection against damage in case of breaks.

To obtain all of these features will usually require absolute fee title to the location. If the pipeline is to be of benefit to the owners of the terrain it crosses by making the product carried (in this case, water) available to them, the applicant will stand a much better chance of acquiring these features in an easement. As a general practice, the applicant can reasonably expect to obtain adequate width, slope rights for cuts and fills, temporary construction space, and permanent road rights with the easement. These are important items; without them, the pipeline

owner may be forced to seek another location.

Lauenstein (*1*) has described many of the problems encountered in using easement locations; and the advantages of the various types of easement have been admirably treated by Flaa and Renshaw (*2*).

Construction

The problems encountered during the construction of a pipeline on an easement require considerable planning and study. Access for men and equipment must be given careful consideration before the easement is obtained to assure adequate width for making surveys as well as for the construction of the line; to make the necessary slopes in cuts and fills; to allow for future replacement of the line; and for perpetual maintenance. In our mechanized age, roads must be available to provide access for personnel, material, and machinery. Usually it is necessary to establish a permanent road for inspection and maintenance of the completed line. In hilly terrain, such a road must often deviate from the location of the pipeline, due to grade conditions. On level ground for which the property owner has reserved surface rights, access roads may present a problem and in many instances may be decidedly impractical because of the high cost of an easement that causes severance with resulting damage to the property. Securing easements along property lines, wherever possible, will often minimize the road and severance difficulty. Where private roads are established on an easement for a pipeline, it may be necessary to prevent public use, which might in time develop into a prescriptive right. In such cases, barricading is often necessary, with periodic inspections to assure the efficacy of the barriers. The existence of barriers, however, impedes the access of the

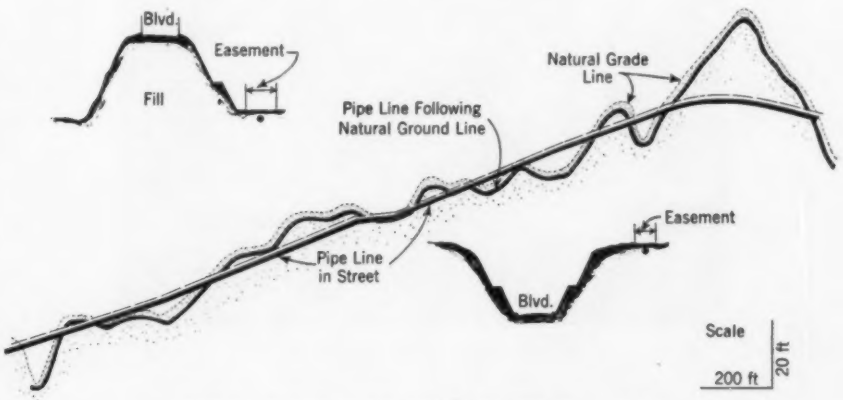

Fig. 2. Profile of Alternative Pipeline Locations

The irregular dark line represents pipeline laid along the natural ground line in an easement adjacent to the proposed roadway. The more even slope represents pipeline laid beneath the thoroughfare after grading.

pipeline owner, who must patrol and maintain the line.

Construction work in an easement can be virtually without difficulty in open, undeveloped terrain; on the other hand, it can be subject to continual interference in areas that are improved or contain natural resources, such as orchards, oil wells, and forests (in government preserves, for example). Serious error can be made in reserving or acquiring inadequate easements through undeveloped territory in which residential development occurs before the pipeline is constructed. Not only is it often impossible to utilize the required equipment in the limited working space remaining, but quite often it is necessary to remove fences, walks, driveways, and shrubbery in order to install the line. Disturbance of the property owner's improvements is a serious damage which is often quite difficult to correct, especially when such improvements were actually constructed by the property owner himself. On this point, Dunshee (*3*) says, ". . . the utility should not attempt to make minor repairs to buildings, irrigation pipes, or fences, or itself attend to the recultivation of soil which may have been packed hard by the construction equipment traveling over it while it was wet. Generally, it is more satisfactory to secure an estimate of the cost of doing this work, paying the property owner a reasonable amount within such an estimate and taking his release at the time of payment. The owner will seldom be satisfied with the quality of work which the utility does, but he will be sure to be satisfied with his own work, even if it is inferior."

Fig. 3. Steel Siphon in Easement

After construction of the pipeline had been completed, a public thoroughfare was dedicated over this site. Unless exclusive easement can be obtained, the pipeline owner must anticipate such situations.

Costs

It is conjectural whether the use of easements will cost less than the use

of public thoroughfares. Access to a public thoroughfare is generally conceded to be more convenient and more reliable than access over private land, particularly improved land bearing buildings, trees, water wells, and the like. Even on undeveloped land containing hills, forests, and marshy areas, the cost of access may be much greater. Inclement weather can halt construction on an easement more quickly and for longer periods than on a thoroughfare. Location on public thoroughfares also presents some difficulties, the restriction caused by both vehicular and pedestrian traffic, for example, tends to increase construction costs. With regard to actual construction operations, easement location appears likely to be less costly in most cases. Factors contributing to the higher cost of thoroughfare location, in this regard, include: pavement breaking; avoiding other substructures; restrictions imposed by traffic; rigid backfill and dirt removal requirements; the need for elaborate barricades and warning lights; and, of course, resurfacing. None of these requirements is ordinarily a condition of easement construction.

It should be remembered, however, that construction through easements is not always preferable. The costs of easement construction can run very high, for the reasons previously mentioned. A good precautionary practice is to photograph, prior to construction, every foot of the easement on which there are private improvements which may require replacement or repair or which stand in proximity to the working area.

Dunshee (*3*) provides a fairly comprehensive list of damages which might occur during pipeline construction on an easement: "Claims arising from the construction of utility facilities are as varied as is the use of the land through which our pipelines . . . pass; they will differ widely with differences in construction methods, with the different types of facilities under construction, and with differences in climatic conditions. They will usually result from the mechanical destruction of growing crops, including pasture; the damaging of fruit trees and vines; the loss or partial loss of fruit and vegetables because of dust; interference with irrigation schedules and consequent loss of crops; damaged fences, ditches, pipes, and other improvements; livestock injured or killed by falling in the trench or becoming trapped in a half-completed tower; livestock that allegedly escapes through an unclosed gate or unrepaired fence and vanishes into thin air. (It is this same unclosed gate that is occasionally blamed for the scrubby calves that are born to purebred heifers.) The soil is packed too hard; the backfill is too loose; the road is so rough that the axle of the farmer's auto is broken; it is so slick that he skids into the ditch."

Damages occurring in constructing pipelines on public thoroughfares are less likely to result in excessive or extraordinary claims and subsequent litigation, since the owners of other facilities on these thoroughfares are in much the same position. More realistic efforts toward mutually acceptable solutions are characteristic of those having facilities on the public thoroughfares. Instances of gross negligence and utter disregard for others' facilities are not condoned; such instances are kept to a minimum through the requirement of a permit to occupy the public thoroughfare.

The right to dispose of the surplus excavated earth on or along the easement as desired is extremely valuable, for without it expensive loading and hauling of this surplus may be required. Usually there is a need for dirt to fill depressions in the land, and the experienced right-of-way man will anticipate such need and acquire the necessary rights, whenever possible, at the time the easement is negotiated.

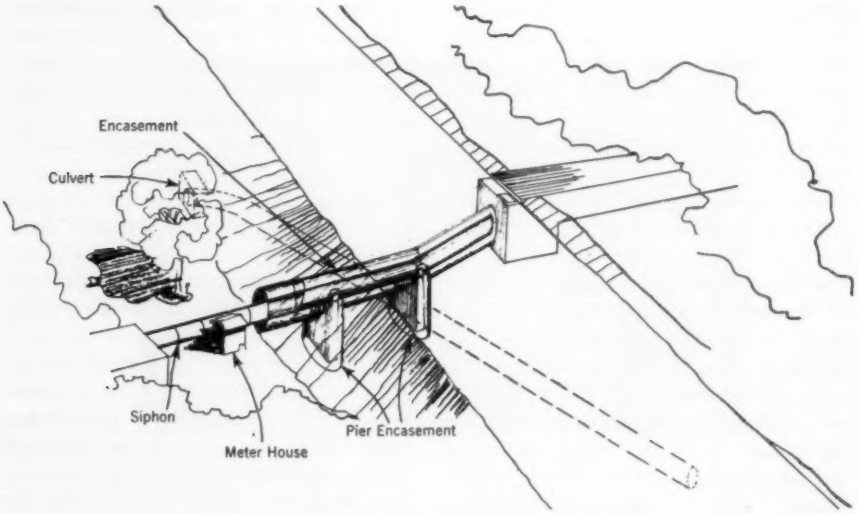

Fig. 4. Encasement Protection for Steel Siphon

The siphon shown is that in Fig. 3 after modifications to accommodate construction of a public thoroughfare over the easement. Both siphon and original piers are encased for protection.

Maintenance

The problems involved in the maintenance of a pipeline on an easement are numerous and must be given thoughtful consideration in choosing between the easement and the public thoroughfare.

To the pipeline owner, it is disconcerting, to say the least, to be notified that his pipeline has broken and is seriously damaging a large building, the corner of which has been constructed over the line without his knowledge; or that his pipeline has got in the way of the "X" Company's excavator while making a cut and is washing out their operations. It is true, of course, that such things could happen on a public thoroughfare as well: but such extreme carelessness and foolish disregard for the public records is rare.

Because pipelines are usually buried out of sight, they can easily be overlooked. People do not usually go about looking for something they do not want to find; and on an easement that "something" may include substructures crossing the proposed location of a new pipeline. Although, by rights, all pipeline owners should make

a thorough search before selecting a route in easements and starting construction, practice indicates that the only sure way to notify everyone of existing substructures is to define the limits of the easement on the ground surface. This may be done by any of several methods, of which fences or posts and stakes are the most common.

While planning a pipeline, allowance must be made for the possibility of subsequent modification to accommodate the landowner's desires or essential public improvements. Figure 3 shows a large-diameter steel water line over which a public street is to be constructed. Figure 4 is a drawing showing how this will be accomplished. Situations like this one certainly must be anticipated unless an exclusive easement, with paramount rights, is obtained. Such easements, however, are comparatively rare. Few today are in the position the railroads once enjoyed, when the landholders often desired the medium of transportation urgently enough to give exclusive easements for it.

It is naturally assumed that all pipelines on easements are properly located therein; that is, that the pipe is in the center of the easement and at sufficient depth not to be damaged by equipment or plows. This latter, especially, is an important factor which every pipeline owner should check in detail if he would avoid future damages.

It is often necessary, for various reasons, to change the location of a pipeline during construction. In such cases, the easement location should likewise be changed. An example of the consequences of locating a water line outside the easement is provided by a recent case in the Los Angeles area. A land subdivider who had located the pipeline easement and was keeping a proper distance from it broke into a high-pressure water pipe located 5 ft outside of the easement limits. The subdivider's tract was badly flooded, causing considerable damage and loss of time. The local water department decided to replace the old line in the street that the subdivider was constructing; no sooner had the new water main been completed and placed under pressure, however, than a temporarily blocked angle gave way and again flooded the subdivider's tract, causing still greater damage and loss of time.

Public Relations

The problem of maintaining good public relations is becoming increasingly important to the pipeline owner; the additional time and effort devoted to a successful education program should be regarded as an investment that will in time bear dividends in decreased controversy and litigation. Burke (*4*) has said, in this regard, "the pipeline industry's management is by no means unmindful of the fact that the problem of public opinion is one that requires effort by every one of us. It is an essential part of the job of each employee. You need the help of the man in the gang, as well as his foreman and superintendent, and you need the help of your management and policy makers." In the same article he describes, in some detail, a plan to follow in the use of easements. "First, we would make every effort during the construction of the line to cause the minimum disturbance to the property owners. We would leave each

piece of property in as near its original condition as possible. Damages would be paid promptly. . . . Second, we would emphasize public relations and stress with our employees and the contractor's employees the need for good behavior toward the public in general and the landowners in particular, during both pipeline construction and operation. . . ."

People, today, want to be informed; even though an event or project may be of no immediate concern to them, the public wants to feel that it is considered important enough to be told what is happening. By publicizing his plans beforehand, and letting the people in the area concerned know what he is going to do and when, the pipeline owner can save a good deal of the effort involved in answering specific questions and may even establish a permanent fund of public good will toward his operations.

It may, of course, be argued that no such problems exist if the public thoroughfares are used. Experience, however, has shown precisely the opposite to be the case: because it is a "public" thoroughfare, the public seems more than ever conscious of its vested interest, and demands early and frequent consultation with those who would "trespass."

Recently, in the Los Angeles area, a difficult public relations situation arose, involving a city street location for a 69-in. diameter water pipe. Unfortunately, the street selected for the line included the main shopping section of the community. For many years the local merchants had complained of a rough and unsightly street, in the center of which a street railway (no longer in operation) held exclusive right of way. After years of agitation, the city officials finally improved the street with a center park area where the railway tracks had been removed. The pipeline project involved excavating in this street just 2 years after it had been improved. This location was by far the most economical of the several alternatives and the unpaved park area offered an ideal location for the line, absolutely free of substructures. Not until numerous meetings had been held with the community leaders and their elected representative was their acquiescence finally obtained. In all the efforts of the pipeline owners, one sound and reasonable argument was offered to the public: namely, that their standard for the selection of the pipeline location was solely economic. It was pointed out that if another location were chosen to satisfy the desires of those who suggested using other streets, then the pipeline owner would be left without any standard upon which to determine what extra cost is justified. For if the first standard—"the most economical location"—is abandoned, then obviously "the sky is the limit" follows.

The pipeline owner must be ready and willing to show the public the basis—economic or otherwise—upon which the selected location was determined.

References

1. LAUENSTEIN, CARL A. Pipeline Location and Right-of-Way Problems. *Jour. AWWA*, **42**:199 (Feb. 1950).
2. FLAA, INGWALD E. & RENSHAW, WILLIAM C. Rights of Way for Pipelines. *Jour. AWWA*, **39**:128 (Feb. 1947).
3. DUNSHEE, B. K. Settlement of Claims Arising From Acquisition of Rights of Way and New Construction Thereon. *Proc. Pacific Coast Gas Assn.*, **42**:60 (1951).
4. BURKE, J. L. Right-of-Way Problems are Management's Problems. *Right of Way*, **1**:23 (Apr. 1954).

Artificial Ground Water Recharge

Task Group Report

A report of Task Group 2440 R—Artificial Ground Water Recharge, presented on May 9, 1956, at the Annual Conference, St. Louis, Mo., by J. J. Baffa (Chairman), Cons. Engr., New York, N.Y. Other members of the group are H. C. Barksdale, C. H. Bechert, M. L. Brashears, L. L. Hedgepeth, F. B. Laverty, A M Rawn, E. B. Showell, L. F. Warrick, and W. F. Welsch.

CONSERVATION of ground water resources through the medium of artificial ground water recharge is widely practiced throughout the United States. In 1951 Task Group 2440 R was established to study and report upon significant developments in artificial recharge practices, insofar as they affect current or future sources of supply for water works.

In 1952, the task group (then under the chairmanship of C. H. Bechert) sent a questionnaire to water resources agencies in each of the 48 states to determine the extent to which artificial recharge was then being practiced and its possible application to local and regional water supply problems. At that time, the group also began to study the available literature on the subject. The results of the questionnaire were reported in the JOURNAL of August 1952 (*1*).

At a meeting of the committee in May 1955, it was decided to reissue the 1952 questionnaire in order to obtain more recent information. In the latter part of 1955, therefore, the questionnaire was sent to the district geologist (or the acting equivalent) of each state.

Interim Developments

Replies to the questionnaire were received from 46 states in 1955. The major development indicated was the increase in the number of states with legislation requiring that water employed for cooling or air conditioning be returned to the ground. In 1952, the replies had indicated that such legislation had been enacted only in New York State. In 1955, Nevada, Oregon, and Utah also indicated such legislation in their replies.

To the list of states in which artificial ground water recharge is practiced as a means of increasing the yield of a specific public water supply were added, in 1955, Indiana, Iowa, Massachusetts, and North Dakota. The replies to the 1952 questionnaire had been negative for these states. It is known, however, that artificial recharge was practiced in each of these states (except North Dakota) prior to 1952; therefore the information received in 1955 is to be considered as supplementing, rather than superseding, the information received in 1952. The replies received in 1955 also indicate that Indiana and Michigan are to be added to the list of states in which

ground water is recharged for industrial supplies.

Since the committee last reported, the state of California has been outstanding in both practice and research. H. O. Banks and his associates have studied and reported upon 87 recharge projects in that state (*2*). F. B. Laverty and H. A. Van der Goot have described the development, in Southern California, of a fresh-water barrier for the prevention of sea water intrusion, using artificial recharge (*3*). The California State Water Pollution Control Board has published a report describing the recharge of industrial wastes and sewage effluents (*4*). In 1954 this same agency published a report upon the travel of pollution in underground waters (*5*). Both of these reports were based upon work done by the Sanitary Engineering Research Laboratory of the University of California, under the direction of H. B. Gotaas. In 1955, the Laboratory also reported the research of W. J. Kaufman and D. K. Todd in methods of detecting and tracing the movement of ground water (*6*). In 1954, A. F. Bush and S. F. Mulford of the Department of Engineering of the University of California reported upon waste water reclamation and utilization (*7*).

The Illinois State Water Survey Division has issued its fourth annual report on the operation of the Peoria infiltration pit for the 1954–55 season (*8*). Experiments with recharge rates are being continued in Nassau County, New York (*9*). A progress report on studies of artificial recharge in the Grand Prairie region of Arkansas was released in May 1955 by the US Geological Survey (*10*). The Texas Board of Water Engineers has published a study of artificial recharge through injection wells at El Paso, Tex. (*11*).

European practices for the artificial replenishment of underground water were comprehensively reviewed in 1952 by the Swedish engineer, O. V. E. Jansa (*12*). Experience in the use of artificial replenishment of ground water resources in western Europe—especially in Great Britain—was reviewed by S. Buchan of the British Geological Survey (*13*). In British practice, the introduction of excess stream flow into wells has improved the quality of ground waters in many areas.

Legislation

As previously indicated, four states (New York, Nevada, Oregon, and Utah) reported legislation requiring that well water employed for cooling or air conditioning be returned to the ground. The New York State law, passed in 1933, declares that in the specific area of Long Island all ground water pumped for air conditioning, refrigeration, or cooling must be put back into the ground (through diffusion wells or recharge basins) in an uncontaminated condition. The Nevada law, passed in 1939 and amended in 1953 and 1955, authorizes the state engineer to prevent ground water waste and requires that water used for air conditioning be returned to the same aquifer within which it originates—that is, poor quality water must be returned to a poor quality water zone, good quality water to a good quality aquifer. In Oregon, it was reported, the state engineer has authority to prevent ground water waste. It was also observed that most air-conditioning and heat pump installations using ground water do return it to the ground. For

Utah, it was reported that the state engineer, under the general provisions of existing law, has required that water employed for cooling or air conditioning be returned to the ground in certain specific areas.

Although negative replies regarding the existence of such legislation were received from New Jersey, North Dakota, Washington, and Mississippi, certain qualifying comments were made. In New Jersey, state regulation, under general water control laws, requires the return of cooling water to the ground in protected areas. In North Dakota, although an act was recently passed proclaiming all ground waters to be the property of the state, no means were established to regulate use, waste, or other practices. In Mississippi, under House Bill No. 7, the state legislature has created a water resources policy commission, one purpose of which is to study the use and misuse of ground water.

The replies to the questionnaire indicated that no state requires that cooling water obtained from a municipal supply be recharged. The replies of nine states declared that there was no problem with respect to cooling water and that no legislation was required. Two states indicated a desire for further study. The immediate desirability of some form of legislation for the recharge of cooling water was indicated by two states and by another it was observed that legislation might ultimately be desirable. Concerning the existence of legislation requiring that surface or treated waste waters be injected into the ground, all 46 respondent states answered in the negative. As to the desirability of such legislation, 8 states replied affirmatively, 15 in the negative. The following comments were made with respect to the use of surface waters for augmentation of ground water:

1. "The matter should be studied."
2. "Action should be taken toward a long-range plan of water control in the areas of greatest need."
3. "If surface waters are injected into the ground there is danger of contamination of ground water. It would be impossible to maintain a check on quality."
4. "Quality of water should be given consideration."
5. "Desirable as a general conservation measure."
6. "Should only be done for specific purposes."

Underground Disposal

To the question whether the state has the power to regulate the underground disposal of waste waters, 22 states gave affirmative answers, 15 negative. The following comments and qualifications were made by those answering in the affirmative:

1. "To a limited extent." (One reply.)
2. "The state health department has limited authority where danger exists to public health." (Two replies.)
3. "Control is through the state health department." (Two replies.)
4. "The state controls oil field brine disposal in deep wells." (Two replies.)
5. "Power is held jointly by the state engineer and the state department of health." (One reply.)
6. "Control is vested in a water pollution control commission." (One reply.)
7. "Statutory authority needs clarification." (One reply.)

TABLE 1

Recharge Projects Reported by States

State	Specific Supplies			State	Specific Supplies		
	Public	Industrial	Irrigation		Public	Industrial	Irrigation
Arizona*	1		*	Nebraska			
Arkansas			1	Nevada			
Alabama		2		New Hampshire			
California*	87		1	New Jersey	4	3	
Colorado			1	New Mexico			
Connecticut	1	2†		New York*	1		
Delaware				North Carolina			
Florida				North Dakota	3		
Georgia				Ohio	2		
Idaho				Oklahoma			
Illinois*		2	1	Oregon		1	1
Indiana	1	1		Pennsylvania		1	
Iowa	1			Rhode Island			
Kansas	§			South Carolina	1		
Kentucky*		30‡		South Dakota			
Louisiana				Tennessee			
Maine				Texas	2		
Maryland				Utah*	1		2
Massachusetts	13			Vermont			
Michigan		1		Virginia		1	
Minnesota	1			Washington*	1		1
Mississippi				West Virginia			
Missouri				Wisconsin	§		
Montana				Wyoming			

* Regional projects reported.
† Not in use at present.
‡ Reported not all successful.
§ Under consideration.

Negative replies included these comments:

1. "No specific law exists." (One reply.)
2. "The state health department has jurisdiction over the safety of water supply from a public health standpoint." (One reply.)
3. "Such a law is sorely needed." (One reply.)
4. "The only recourse (in case of contamination) would be as private individuals, by collecting damages." (One reply.)
5. "The state and the gas board can regulate to some extent the disposal of oil field brines to deep wells." (One reply.)

Those who answered neither "Yes" or "No" commented as follows:

1. "Some ex-post-facto remedial authority exists in the state department of health." (One reply.)
2. "Not sure." (Two replies.)
3. "Power implied but not specifically stated." (Two replies.)
4. "Do not know." (Two replies.)
5. "Need more definite laws but have gotten by with some control." (One reply.)

To the question whether treated domestic and industrial waste waters were being used to recharge aquifers, there were 44 negative answers and 2 affirmative answers—the latter two, Idaho and New Jersey. One of the respondents who answered in the affirmative commented that water being put into the ground was primarily for the purpose of waste disposal. Three of the respondents answering in the negative commented as follows:

1. "Some waters are used for secondary oil removal."
2. "Two or three plants return cooling water to injection wells."
3. "Waste waters going into the ground for disposal purposes and not for recharge."

Present Recharge Practices

In answer to the question "If artificial recharge is being practiced in your state, is it being done primarily to: [1] prevent salt water intrusion; [2] conserve water generally; or [3] solve specific water problems?" The following answers were received:

1. Prevent salt water intrusion. (4 "Yes," 3 "No.")
2. Conserve water generally. (8 "Yes," 3 "No.")
3. Solve specific water problems. (14 "Yes," 2 "No.")

In Arkansas and New Jersey, it was reported, recharge is practiced both for general conservation and for solving specific problems. For California and New York, the first two considerations were reported; for Georgia, all three; and for Connecticut, the first and third.

Compilation of data from both the 1952 and 1955 questionnaires indicates that some form of ground water recharge is practiced in 24 states and is being considered in at least two more. The number of projects reported for various states is shown in Table 1. In view of conflicting replies in the 1952 and 1955 questionnaires, the data in Table 1 are not to be considered numerically exact but rather as an indication of the prevalence of recharge practices and the general locale of recharge projects, without reference to capacity.

Future Possibilities

In reply to the question whether there were areas in the state not presently utilized, in which it would be possible to recharge aquifers, there were 36 affirmative answers, and 4 negative answers. Of the 36 affirmative answers, 18 respondents indicated they do not practice recharge at the present time.

In reply to the question whether the possibilities and relative economic benefits of recharging aquifers with waste waters (including storm flow) had been compared with those of developing new sources of supply (whether internally or by import), there were 43 negative answers. Only California and New York replied in the affirmative, although the respondents from 27 states declared that such studies should be made. Of these 27, three commented that future application would be to local situations and not on a regional basis; and nine indicated they do not practice recharge at the present time. Respondents from 23 states felt that recharge of aquifers was likely to be the solution to future ground water shortages; of these 23, thirteen do not practice recharge at the present time.

Conclusions and Recommendations

The conclusions of the committee are as follows:

1. Artificial recharge of underground reservoirs is becoming more prevalent and will undoubtedly increase in the future.
2. At the present time artificial recharge is practiced on a regional scale in only a few areas; other regions, however, are under investigation.
3. The importance of the application of artificial recharge to local situations, even for small projects, is not to be minimized.
4. The status of the art is such that each situation requires individual study and investigation.

It is recommended that the task group report biennially upon developments in

legislation, research, design, and operating practices and attempt to assemble all data that may be of value to the water works profession.

References

1. TASK GROUP REPORT. Artificial Ground Water Recharge. *Jour. AWWA*, **44**:682 (Aug. 1952).
2. BANKS, H. O., ET AL. Artificial Recharge in California. Paper presented before the Hydr. Div., ASCE, Austin, Tex. (Sep. 8, 1954).
3. LAVERTY, F. B. & VAN DER GOOT, H. A. Development of a Fresh-Water Barrier in Southern California for the Prevention of Sea Water Intrusion. *Jour. AWWA*, **47**:886 (Sep. 1955).
4. Field Investigation of Waste Water Reclamation in Relation to Ground Water Pollution. Publication No. 6, State Water Pollution Control Board, Sacramento, Calif. (1953).
5. Investigation of Travel of Pollution. Publication No. 11, State Water Pollution Control Board, Sacramento, Calif. (1954).
6. KAUFMAN, W. J. & TODD, D. K. Methods of Detecting and Tracing the Movements of Ground Water. Annual Progress Report No. 1, Eng. Research Lab., University of California, Los Angeles, Calif. (1955).
7. BUSH, A. F. & MULFORD, S. P. Studies of Waste Water Reclamation and Utilization. Publication No. 9, State Water Pollution Control Board, Sacramento, Calif.
8. Fourth Annual Report on the Operation of the Peoria Infiltration Pit. Illinois State Water Survey Div., Urbana, Ill. (1955).
9. WELSCH, W. FRED. Conservation of Ground Water, Long Island, N. Y. Paper presented at the New Jersey Section Meeting, AWWA, Atlantic City, N. J. (Oct. 20, 1955).
10. Progress Report on Studies of Artificial Recharge in the Grand Prairie Region, Arkansas. US Geol. Survey, Washington, D.C. (May 1955).
11. SUNDSTROM, R. W. & HOOD, J. W. Results of Artificial Recharge of the Ground Water Reservoir at El Paso, Texas. Bul. 5206, Texas Board of Water Engrs., Austin, Tex. (Jul. 1952).
12. JANSA, O. V. E. Artificial Replenishment of Underground Water. *Proc. Intern. Water Supply Assn.*, Paris (1952).
13. BUCHAN, STEVENSON. Artificial Replenishment of Aquifers. *J. Inst. Water Engrs.* (Br.), **9**:111 (Mar. 1955).

Reserves of Ground Water in Iowa

Eugene H. Walker

A paper presented on Oct. 13, 1954, at the Iowa Section Meeting, Cedar Rapids, Iowa, by Eugene H. Walker, Geologist, Ground Water Branch, US Geological Survey, Iowa City, Iowa. Publication authorized by the Director, US Geological Survey.

IOWA is favored by the presence of a number of aquifers that can provide the large yields required for municipal and industrial supplies. These aquifers are heavily pumped throughout the state, in some localities because of the lack of adequate supplies of surface water, in others because of such desirable characteristics of ground water as uniformly low temperature and freedom from the sediment and contaminating substances common in untreated surface waters. The lowering of water levels which inevitably accompanies such heavy pumping raises the important questions of how long the supplies will sustain present pumping rates, and how great an increase in pumpage is possible.

The purpose of this article is to present a few observations and conclusions on the subject of future ground water supplies in Iowa. It is based on data collected by the Iowa Geological Survey and the US Geological Survey under their cooperative program of investigation of ground water resources, and on previous studies such as that by Norton and others (*1*).

The aquifers of major importance in the state—those capable of supplying present municipal and industrial demands (and perhaps, in the future, irrigation demands)—can be divided into two categories on the basis of their expected future performance. In one group are the bedrock formations that are tapped for water at considerable depths. These formations are able to sustain heavy pumping because of the vast reserves of water in storage, but in many localities water levels are falling because rates of pumping exceed the slow rates of replenishment. In the future, water will be produced from these formations at increasing cost as the pumping lifts increase. In the second group are the shallow aquifers —mainly bodies of sand and gravel and (more rarely) bedrock limestone or sandstone—which lie in the valleys of major streams and which, under certain conditions, are replenished with water from the beds of the rivers. Pumping of wells in these shallow aquifers near the streams causes an initial drawdown of water level and the establishment of a water level gradient from the river to the well; thereafter, a yield equal to the rate of flow from the river can be sustained indefinitely without further drawdown. The yields procurable from suitably located well fields of this type are measured in millions of gallons a day. Similar opportunities exist close to certain Iowa lakes and ponds which furnish recharge to adjacent permeable formations.

Deep Rock Aquifers

Most of the large-capacity wells in Iowa are drilled to one or more of

TABLE 1

Principal Bedrock Formations of Iowa

Age	Description	Water-bearing Characteristics
Cretaceous	Graneros shale	Impermeable
	Dakota sandstone	Water bearing
Pennsylvanian	Shales; thin limestones; sandstones, mostly thin	Low yields
Mississippian	Several limestones; thin shale beds	Fair to low yields
	Maple Mill shale	Impermeable
Devonian	Sheffield formation Lime Creek shale	
	Cedar Valley limestone	Water bearing
Silurian	Niagara dolomite	
Ordovician	Maquoketa shale	Impermeable
	Galena dolomite	Water bearing
	Decorah and Platteville formations, thin limestones and shales	Relatively impermeable
	St. Peter sandstone	Water bearing
	Prairie du Chien group, dolomite with some sandstone	
Cambrian	Jordan sandstone	
	St. Lawrence formation, mostly dolomite	Relatively impermeable
	Franconia sandstone	
	Dresbach sandstone	Water bearing
Pre-Cambrian	Sandstones, quartzite, granite	Relatively impermeable

the water-bearing formations listed in Table 1. These aquifers are commonly tapped at considerable depth, from a few hundred to more than 3,000 ft below the surface. The waters derived from such depths are under artesian pressure and rise well above the tops of the aquifers—at some places to within a few feet of the surface. In the early part of the century, before loss of pressure, strong flows at the surface were procured at many sites.

All the water-bearing zones older than the Dakota sandstone of Cretaceous age are of great extent in Iowa. They are marine strata laid down as sheets on the floors of ancient seas. At some time after their deposition, a

broad warping of the crust in this part of the continent cast the whole packet of strata into their present attitude of inclination toward a deep trough in the southwestern part of the state. The strata rise gradually to the surface toward the west, the north, and the east. The sandstone of Cretaceous age occurs only in the western part of the state. It lies like a sheet upon a surface eroded across the older, warped formations. Figure 1 shows approximately the zones in which the bedrock formations provide large yields of water. It should, however, be understood that the formations themselves extend more widely than the zones indicated.

The Dresbach sandstone is the oldest formation in Iowa that yields important quantities of water. Large supplies have been developed from it at a number of towns and cities along the Mississippi Valley, such as Dubuque, Clinton, and Davenport. The artesian pressure in the formation originally caused large flows at the surface from wells located in the valley, but the water level is now considerably below the ground surface in most of these wells.

The Dresbach sandstone barely comes to the surface in the extreme northeastern part of Iowa and its nature in the state is known mainly from well samples. In eastern Iowa the formation consists of two beds of coarse-grained sandstone separated by shaly and calcareous beds, and the total thickness at most places is many hundreds of feet. The distinction between the two sandstones is lost to the west and south, where the formation becomes thinner. The formation may be only a few tens of feet thick in the central part of Iowa.

It appears that the Dresbach sandstone will yield considerable amounts of water of acceptable quality through a zone that extends far west of the present limited belt in which it is developed. Few records are available because the younger overlying formations (notably the Jordan sandstone) yield such bountiful supplies that there has been little incentive to drill deeper. The zone of potential development, bounded by diminishing yields and lower quality of water, extends farther west along the northern margin of the state than it does some distance to the south. At Mason City the quality of the water from the Dresbach sandstone verges on the unsatisfactory and at Cedar Rapids the quality is below what is generally acceptable. At both places the formation is reported to have yielded less than would supply a small town.

The principal bedrock aquifer in Iowa is the zone that extends downward from the top of the St. Peter sandstone through the Prairie du Chien group to the bottom of the Jordan sandstone. Most of the deep wells of large capacity in Iowa are finished in this aquifer. Yields run to hundreds of gallons a minute in most parts of the area in which the zone has been developed (*see* Fig. 1). The Jordan sandstone is the principal water-bearing formation in this zone, followed by the Prairie du Chien group and then the St. Peter sandstone. At a few places in the state the St. Lawrence dolomite, beneath the Jordan sandstone, makes significant contributions of water.

In Iowa the formations can be observed at the surface only in the northeastern part of the state. Numerous good well logs furnish information on their character and thickness throughout most of their subsurface extent.

The Jordan sandstone consists almost wholly of quartz grains of me-

dium to coarse size, for the most part well worn and rounded. In the northeastern part of Iowa the sandstone is not very strongly cemented and some zones may be so weak as to cave into wells. The paucity of cementing material between the grains accounts for the large amount of storage space for water and for the high permeability of the formation. The sandstone is about 50–100 ft thick through most of eastern and north central Iowa. The thickness decreases and the degree of cementation increases as the formation is traced to the southwest.

The Prairie du Chien group consists mainly of dolomite, but includes beds of sandstone. The New Richmond sandstone can be identified in the logs of almost all wells that penetrate the greater part of the Prairie du Chien group. The Prairie du Chien is several hundred feet thick through most of the eastern part of the state. Water is yielded from crevices in the dolomites, as well as from the beds of sandstone.

The St. Peter sandstone, famous for the roundness and frosted surface texture of its quartz grains, is a pure sandstone of medium grain, with little cementing material. It is rarely more than 50 ft thick, and it yields much less water than do the immediately underlying formations. Steel casing is ordinarily set through the St. Peter sandstone in wells that extend to the deeper

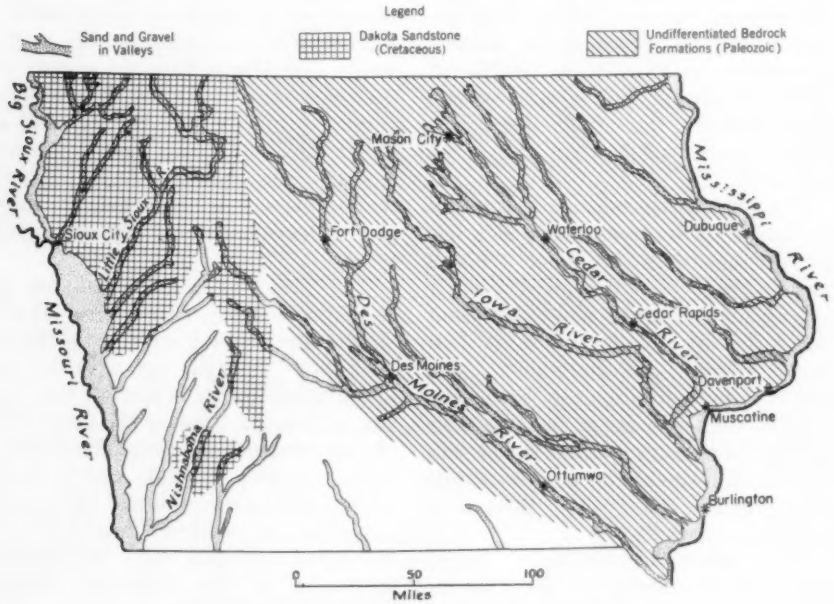

Fig. 1. Extent of Principal Aquifers of Iowa

The Dakota sandstone and undifferentiated bedrock indicated comprise the major deep rock aquifers of Iowa. Alluvial deposits of sand and gravel provide shallow aquifers of large, sustained yields.

zones, in some places because the sandstone tends to cave into wells, in other places to shut out water of poor quality in the upper part of the sandstone.

Development of Deep Aquifers

The approximate limits of present development of the aquifer zone comprising the St. Peter, Prairie du Chien, and Jordan formations lie along a boundary that may be drawn from the southeast corner of Iowa toward Des Moines, and thence north-northwestward to the northern boundary of the state, as shown in Fig. 1. The boundary is, of course, gradational and indefinite: some successful wells lie west of it, some unsuccessful wells lie east of it. Several factors determine the approximate position of the boundary as drawn. The formations do not exist in the northwestern part of the state, having been eroded away before the deposition of the Dakota sandstone. The expectable yield declines toward the southwest because the formations become less porous and permeable in that direction, and the sandstones become thinner and more fully cemented. The mineral content of the waters increases toward the west, southwest, and south to such an extent as to make the quality of the water unacceptable; the content of dissolved solids begins to exceed 1,000 ppm approximately along the boundary indicated. To the southwest the increasing depth of the formations and consequent increased cost of drilling, coupled with the uncertainties of volume and quality of yield, have contributed to defining the useful extent of the zone.

Numerous wells yield water from these formations in the area shown in Fig. 1, but it is not to be assumed that the potentialities of the formations have been seriously diminished. Vast reserves exist even at the sites of heaviest pumping, and at some miles from such sites the original pressure surface has been scarcely affected by the pumping.

The several limestones and dolomites that occur in the succession of strata above the St. Peter sandstone (*see* Table 1) are valuable aquifers through the central and eastern parts of the state, though not of the rank of the St. Peter and Jordan aquifer zone except at a few localities where special conditions favor large yields. The Galena dolomite and the aquifer zone comprising the Cedar Valley limestone and the Niagara dolomite are in general of much more importance than the limestones of Mississippian age.

The limestone and dolomite aquifers yield best where they are relatively near the surface. The dolomites yield some water from pores created originally by the process of dolomitization, but most of the water in the calcareous formation occurs in openings that decrease in size and frequency with increasing depth from the surface—that is, in shattered zones and the openings widened by solution. Consequently the yield of the formations decreases as their depth increases; at the same time, the quality of the water becomes worse, partly because the water-bearing beds are in close association with shale beds, and partly because the water has been long in contact with soluble minerals. Repeated attempts to develop good supplies from these formations in the south central and southwestern parts of Iowa have failed because of the poor quality of the water and the low yields.

The Dakota sandstone is the principal bedrock aquifer of northwestern Iowa. Through most of its extent

there are no other bedrock aquifers of importance. Yields from the sandstone are sufficient to meet the need of the towns and cities of moderate size in the northwestern part of the state. The sandstone thickens and thins greatly from place to place, for it was deposited upon a surface of hills and valleys eroded across the older formations. Rarely is it found to be as thick as 150 ft, and it averages approximately 50 ft. It is a coarse-grained, open-textured sandstone containing some pebbly zones. The permeability is usually good. The sandstone is impure in the sense that it contains fragments of many minerals other than quartz. The brown to red color of the sandstone where it outcrops at the surface reveals the presence of iron-bearing minerals. Water from the Dakota sandstone is of good quality at a number of locations, but at many others it is very hard and contains objectionable amounts of iron and other dissolved mineral substances.

TABLE 2

Decline in Water Level of Deep Rock Aquifers

Location	Source	Period of Record *years*	Decline in Water Level—*ft*
Dubuque	Dresbach sandstone	70	247
Ottumwa	Prairie du Chien group—Jordan sandstone aquifer zone	65	100
Mason City	Prairie du Chien group—Jordan sandstone aquifer zone	42	130
Cedar Rapids	Niagara dolomite and deeper formations	14	55

Supply of Artesian Waters

Much of the water pumped from bedrock aquifers at many sites of heavy pumpage represents drafts on storage exceeding the local rates of replenishment. This conclusion is based on the recorded evidence of a progressive decline of water levels at a number of sites where these aquifers have been heavily pumped for many years. Table 2 shows a few prominent examples of such decline in artesian pressure; many others could be cited.

The declines in water level represent a loss of head locally. The materials comprising an artesian aquifer and the water in it are an elastic system, together bearing the weight of the overlying formations. Theoretically, the surface of the ground subsides a little during the gradual decline of artesian pressure, though this effect has not been noted anywhere in Iowa. A water-bearing formation itself is somewhat elastic and becomes compressed as more and more of the load that was borne by the water pressure is transferred to the formation during the slow loss of head. The ground level has sunk several feet in a few areas in the United States where pumping has greatly lowered water levels, but no subsidence of this magnitude is expected in Iowa within the foreseeable future.

The low rates of replenishment of the artesian aquifers at most sites of pumping are the result of two causes: the considerable distance from the site of intake, and the slow movement of the water through the formations.

Various types of evidence indicate that the water obtained from the deep-lying aquifers at most pumpage sites entered the aquifer at points of intake 10–100 (or more) miles distant. The very existence of artesian conditions depends upon the presence over the water-bearing formation of impermeable or slightly permeable beds which prevent or impede the upward escape of water. The upward pressure prevents water from entering locally, and even if the pressure is reduced the low permeability of the confining beds impedes local recharge. A comparison of the water level fluctuations in a shallow–water table well and a deep artesian well also indicates a distant intake area. The lower graph of Fig. 2 shows how the water level in a well only 12 ft deep rises and falls through the season of recharge in winter and the season of discharge in spring and summer. The fluctuations in water level in the deep artesian well reflect seasonal pumping for air conditioning in Cedar Rapids. If the well were remote from the effects of such pumping, the principal fluctuations would be due to changes in barometric pressure. No effects of seasonal precipitation can be distinguished, so thoroughly are they dampened out because of the distance from the well to the area where the formations receive recharge. The water level in the artesian well would respond to a series of dry or wet years, but very sluggishly, perhaps with a lag of a year or even a number of years.

The water in the aquifer zone comprising the St. Peter sandstone, Prairie du Chien group, and Jordan sandstone apparently moves at rates of about 5–30 ft a year. These rates vary with the gradient of the pressure head surface and the permeability of the formations, both of which differ from place to place. The rates of movement were derived from sparse data, but they are comparable to the rates determined with better data for bedrock aquifers elsewhere in the nation.

The aquifers transmit large volumes of water despite the slow rates of flow because of their considerable thickness and wide lateral extent which provides a large cross-sectional area for flow. With these facts in mind, it is easier to understand how pumping concentrated at a given spot can exceed replenishment and cause progressive lowering of the water level.

The rates of water level decline in the artesian aquifers at sites of heavy pumping will decrease only when the rates of pumping become stabilized instead of continuing to increase year by year in response to the increasing demand for water by a prosperous, growing economy and population. With constant rates of pumping, drawdowns would diminish with the passage of time, as the areas in which measurable drawdowns exist became broader, and conditions approached closer and closer to an equilibrium (*2*). Each increase in pumpage, however, upsets whatever partial equilibrium may have been reached, and causes an accelerated decline of water level which will decrease only when equilibrium is approached at a lower level.

The supplies of water available from the deep aquifers (ignoring the pumping lifts that may be required to recover them) are so large that no exhaustion of the supplies impends in the foreseeable future. The Jordan sandstone contains about 2.3 bil gal of water per square mile, assuming it to have an average thickness of 75 ft and a storage value of 15 per cent, quite reasonable figures through much of eastern Iowa. The amount stored

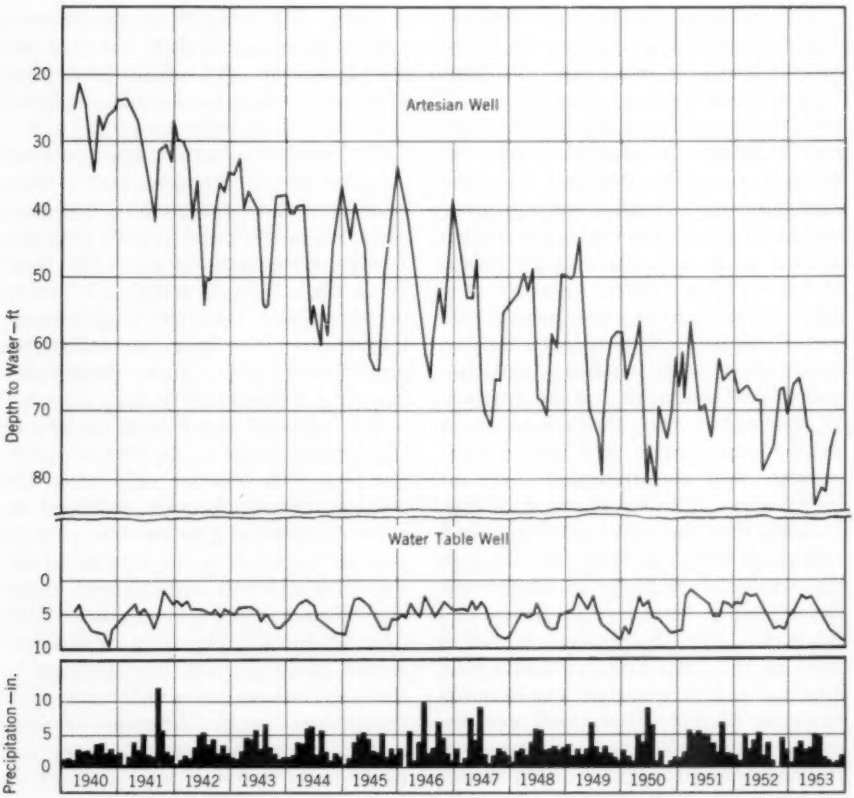

Fig. 2. Precipitation and Water Level at Cedar Rapids, 1940–53

Chart at bottom shows annual precipitation in inches. The upper line graph was recorded for an artesian well 1,450 ft deep in bedrock; the lower graph, for a water table well 12 ft deep in glacial drift.

in the aquifer zone comprising the St. Peter, Prairie du Chien, and Jordan formations is no doubt considerably larger.

The amount that can be withdrawn before artesian pressure is exhausted at any locality is very large, even though it is but a fraction of the total amount in storage. The artesian storage coefficient of a sandy artesian aquifer can be taken, as a rough approximation, to be about 0.000005 per foot of thickness of the aquifer (*2*). Assuming again that the Jordan sandstone is about 75 ft thick, then the artesian storage coefficient may be about 0.000375. To state this in other terms, about 78,000 gal of water might be derived by lowering the artesian water level only 1 ft over a square mile. Again, the yield from the entire aquifer zone comprising the St. Peter sandstone, Prairie du Chien group, and Jordan sandstone would be considerably larger than this figure of 78,000 gal.

If heavy pumping lowered the water level to the top of the aquifer, thereby exhausting artesian pressure locally, then water table conditions would exist and further pumping would empty the pores of the aquifer. The yield per foot decline of water level under these conditions would be vastly greater than under artesian conditions—in the ratio of 0.15 to 0.00035 for the Jordan sandstone, if the figures given are reasonable.

The event to be foreseen and provided against, then, is the lowering of water levels at certain places to such a degree that costs of pumping lift will gradually make the use of the water uneconomical for a number of purposes. Such rising costs, in areas where water is not available from other sources, will inevitably limit economic development, for it is now generally realized that large supplies of water are a necessity for most industries.

Conservation of Artesian Pressure

A number of measures to retard (or even to reverse) the trend of falling water levels have been employed in many parts of the nation where problems are more acute than they currently are in Iowa. Such measures will be applied in Iowa sooner or later. In general, they consist of making more efficient use of the available ground water and artificially increasing the amount of ground water present.

In many cases it is possible to make far more efficient use of a given volume of water than is being done by practices that were developed in the past or in heavily watered parts of the industrial East. The reuse of water offers the largest opportunities for savings. Practices at a steel plant near Los Angeles provide a striking example. There, by repeated cooling and recirculation, only about 1,400 gal of water is required for the production of a ton of steel as compared with the 65,000 gal per ton used in some eastern steel mills (*3*). Reclaimed sewage is now being used at many places throughout the nation; the purchase by a large steel mill of all the sewage discharge of Baltimore is the most prominent case that occurs to the author.

Very large amounts of ground water are saved when water pumped for cooling and altered only by a rise in temperature is returned to the ground water reservoir instead of being discharged at the surface. This practice is common in a considerable number of places at present and will unquestionably be introduced in others. Legislation makes it compulsory in parts of Long Island, N.Y., and probably will do so in other areas, in the course of time.

At many sites a single aquifer is being pumped, but examination can frequently reveal the presence of another aquifer that may be pumped to relieve some of the load on the first. An excellent example is provided by the recent developments at Dubuque, where it was found that the alluvial deposits in the Mississippi Valley, a hitherto untouched source of ground water, could furnish very great supplies and decrease the pumping load on the deep sandstone aquifers.

Throughout most of Iowa there exist large stores of ground water not highly valued at present because of objectionably high mineralization or corrosiveness. There seems to be no reason why these waters cannot be developed for uses in which quality is not an important consideration—for example, cooling, one of the largest uses of ground water. These waters of inferior chemical quality should be looked upon as a source for the future, when increased demands and the de-

velopment of less expensive techniques of demineralization will bring them into use for common purposes, just as improved techniques in the last few years have made commercial ore out of certain low-grade iron deposits.

Supplies of Shallow Aquifers

Iowa is fortunate to have a number of shallow aquifers that offer sustained yields, in some places very large, owing to favorable conditions for recharge from permanent bodies of surface water not far from the potential pumping sites. These aquifers are mainly the open-textured deposits, of good permeability, that lie beneath the flood plains of the major river valleys of the state (Fig. 1) and receive recharge from the rivers.

The permeable deposits in the valley floors consist mainly of sand and gravel laid down by the waters released during the melting of the last glacial ice sheet. Such coarse-grained alluvial material is restricted to the valleys that drained the ice front and is not found in a number of minor valleys that head south of Des Moines, in the south central part of Iowa.

The alluvial deposits of sand and gravel reach a thickness of more than 200 ft in the Mississippi Valley at Dubuque and seem to be almost as thick at a number of other places along the valley. The extensive alluvial deposits along the Missouri River also attain a thickness of more than 200 ft at some locations and the alluvium is also believed to be thick in the valley of the Big Sioux River. The deposits of sand and gravel are almost as thick along certain stretches of the principal valleys of the interior of Iowa, but thin out to a few feet along the upper reaches of minor tributaries. The thickness of alluvium at a given site can rarely be predicted with much accuracy, because of unforeseeable geologic factors, such as branches of bedrock hidden under shallow cover.

The sand and gravel are coarsest along the major valleys, where stream velocities were highest. Well records along the Mississippi Valley show that considerably more than half the material can be classified as gravel, and the rest mainly as sand. Silty layers appear prominently only in the uppermost 10–20 ft. Most of the gravel is of walnut size and smaller, but a small percentage is of cobble size, a few inches in diameter. The ratio of gravel to sand and silt, and the size of the gravel, both decrease along the lesser streams of the state, but here again it is difficult to predict what will be found at a given site, and test drilling should always precede the drilling of a production well.

Creviced limestone or permeable sandstone cropping out in the river bed, or under sand and gravel, forms useful aquifers at a number of places in the state. Such is the case at Waterloo on the Cedar River, where very large sustained yields are obtained from the shattered and creviced limestone of Devonian age which receives water from the river.

Infiltration

The water drawn from wells tapping permeable deposits in valley floors near streams becomes, after a sufficiently prolonged period of pumping, largely river water. When a well is first pumped, water is taken from storage locally and a cone develops. When the cone has spread to the zone of intake from the river (which usually involves the river bed for some distance out from shore), water is induced to enter the formation and to flow down the

water level gradient to the pumped well. Eventually a very large percentage of this yield is derived from the river, and only a little from the land. In its passage through the ground, the water is filtered of the suspended sediment, organisms, taste, and odor that usually characterize river water during certain parts of the year. The temperature of water from such a well changes somewhat during the year in response to the seasonal temperature changes of the river water, but the total range of temperature of the infiltrated water is far less than that of the river water (*4*).

The sustained yield of an infiltration development equals the amount of flow that can be developed from the river to the well site. This depends on the permeability of the formation, the thickness of saturated material, the effectiveness of the connection with the river, the distance to the river, the extent of the well field along the river, and even the temperature of the water (which modifies its viscosity—for example, water is roughly twice as viscous at 40 as at 90°F).

At favorable sites the sustained yields from infiltration can be enormous. One of the largest installations that has been described is at the Indiana Ordnance Works on the west bank of the Ohio River near Charlestown, Ind. At this location seven collector-type wells along 2 miles of river front can provide a sustained yield of about 66 mgd (*5*). Tests performed for the city of Dubuque show that it will be possible to develop a sustained yield of more than 100 mgd from the sand and gravel of the Mississippi Valley along part of the city's waterfront.

At present the largest infiltration development in Iowa is that which supplies the city of Des Moines with about 20 mgd. The development consists of an infiltration gallery in a sheet of sand and gravel about 20 ft thick along the valley of the Raccoon River, which joins the Des Moines River at the city. The flow of water from the river to the infiltration gallery does not meet water demands during periods of low river stage; at such times water is pumped from the river to shallow basins located to the landward side of the gallery, thereby raising the water table by percolation. A dam upriver impounds water that may be released when needed at very low river stages.

The method practiced at Des Moines to supplement available ground water by spreading surface water on permeable deposits seems destined to be applied much more widely in states similar to Iowa. It is much used in Europe; in Sweden, for example, more than 10 per cent of the municipal water is thus supplied (*6*).

The quality of water derived from the valley floor deposits is ordinarily much superior to that from the deep artesian aquifers. Total mineral content and hardness are much lower. At most places iron is the only substance that occurs in objectionable concentration in the waters from alluvial deposits. Ground water for the increasing practice of supplemental irrigation in Iowa is to be sought in these shallow aquifers rather than in the deep aquifers, not only because of the differences in well costs but also because the deep waters at many places contain sodium in amounts that may be harmful to the soil if the water is applied for long periods of time.

Summary

Immense reserves of ground water under artesian pressure exist in Iowa

to meet future needs. At a number of places in the state, heavy pumping over the years has caused a progressive decline of the pressure surface and water levels. It seems likely that artesian pressures will continue to decline because of the gradual increase in pumping that is anticipated. The deep ground water is often cheaper to develop than surface water, and it is the only source at many points remote from surface water supplies.

Higher costs will of course attend the higher pump lifts as artesian pressure declines. At some places these higher costs will compel the consideration of less expensive sources of water, if available, or of conservation measures to slow the downward trend of pressures.

Very large sustained yields of ground water can be developed at many locations along the valleys of the principal rivers on the margins and in the interior of Iowa. The water is in general of better quality than the water from the deep aquifers. These supplies are scarcely developed yet. It appears certain that the location of developments requiring large, assured supplies of ground water—such as certain types of industries, and irrigation projects—will be determined in the future by the location of thick and permeable alluvial deposits along the valleys.

References

1. Norton, W. H., et al. Underground Water Resources of Iowa. *Annual Rept. Iowa Geol. Survey*, **21**:29 (1912).
2. Theis, C. V. The Significance and Nature of the Cone of Depression in Ground Water Bodies. *Econ. Geol.*, **33**:889 (1938).
3. Bello, Francis. How Are We Fixed for Water? *Fortune*, **49**:120 (Mar. 1954).
4. Rorabaugh, M. I. Stream Bed Percolation in Development of Water Supplies. *Proc. Intl. Union of Geodesy*, **2**:165 (1951).
5. Kazmann, R. G. River Infiltration as a Source of Ground Water Supply. *Trans. ASCE*, **113**:404 (1948).
6. Jansa, O. V. E. Artificial Ground Water Supplies in Sweden. *Sci. Conf. on Conservation and Utilization of Resources, UN Dept. Econ. Affairs*, **4**:102 (1951).

Nomographs for the Rapid Analysis of Aquifer Tests

Irwin Remson and T. E. A. van Hylckama

A contribution to the Journal by Irwin Remson, Geologist, Ground Water Branch, US Geological Survey, and T. E. A. van Hylckama, Research Specialist, Seabrook Farming Corp., Seabrook, N.J. Publication authorized by the Director, US Geological Survey.

THE coefficients of transmissibility and storage are two important aquifer characteristics determined during many ground water investigations. The coefficient of transmissibility indicates the ability of an aquifer to transmit water; in US Geological Survey usage, it is expressed as the rate of flow of water (in gallons per day) through a vertical strip of aquifer, 1 ft wide and extending the full saturated height, under a hydraulic gradient of 100 per cent at the prevailing temperature of the water. The coefficient of storage is the amount of water released from storage in a unit vertical prism of the aquifer as the result of a unit decline in head, expressed as a decimal fraction. The coefficients are used to predict drawdowns under given conditions of discharge or recharge.

The coefficients of transmissibility and storage may be determined by applying the Theis nonequilibrium formula to data from aquifer tests (*1*). A graphical solution is effected by plotting the test data and comparing the resulting curves with type curves (*2*).

Several nomographs and computing devices have been devised to facilitate the use of these methods. Jeffords has devised a nomograph which solves a straight-line approximation of the nonequilibrium formula (*3*). Once the transmissibility and storage coefficients have been determined, drawdowns under given conditions of discharge or recharge may be computed by means of the nomograph of Commons (*4*), the nomograph of Chow (*5*), the slide-rule of Theis and Brown (*6*), or the electrical computer devised by the senior author and M. H. Halstead, not yet described in the literature. None of these methods, however, permits the solution of aquifer tests by means of the Theis nonequilibrium formula.

A set of nomographs that permits determinations of transmissibility and storage while the test data accumulate is described in this paper. It supplements the method of matching curves by permitting a rapid field evaluation of the data.

Theory

The Theis nonequilibrium equation may be written:

$$s = \frac{114.6Q}{T} W(u)$$

in which $W(u)$, called the "well function of u," replaces the integral expression:

$$\int_u^\infty \frac{e^{-u}}{u} du$$

where:

$$u = \frac{1.87r^2S}{Tt}$$

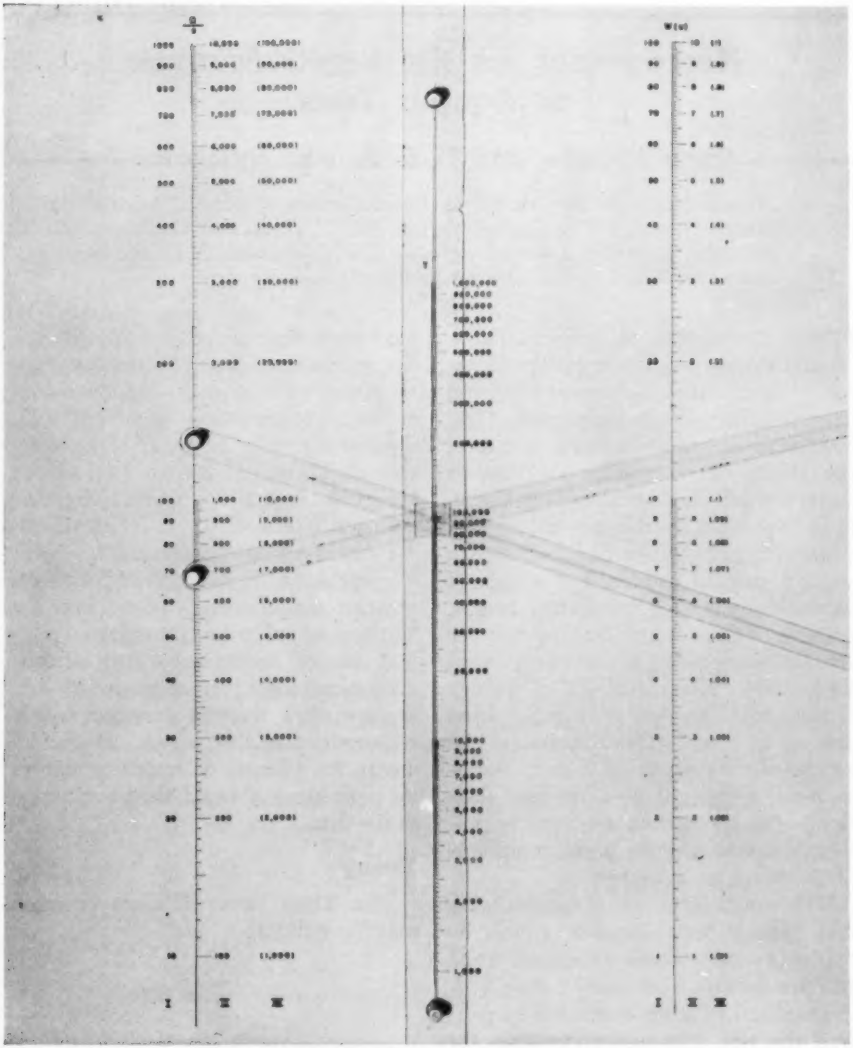

Fig. 1. Nomograph Adapted to the Expression: $\frac{T}{114.6} = \frac{Q}{s} W(u)$

In all of these, s is the drawdown (in feet) at any point in the vicinity of a discharging well, Q is the discharge rate of the pumped well (in gallons per minute), T is the coefficient of transmissibility (in gallons per day per foot), S is the coefficient of storage, r is the distance (in feet) from the discharging well to the point where s is measured, t is the time (in days) since pumping began, and e is the natural logarithm base.

Drawdowns s_1 and s_2 are obtained from an observation well at times t_1 and t_2 during an aquifer test. The values may be substituted in the nonequilibrium equation, the results rearranged, and R set equal to the quantity $\frac{1.87r^2S}{T}$. Because:

$$W(u_1) = \int_{u_1}^{\infty} \frac{e^{-u}}{u}\,du$$

and:

$$W(u_2) = \int_{u_2}^{\infty} \frac{e^{-u}}{u}\,du,$$

the resulting equations may be written:

$$\frac{T}{114.6} = \frac{Q}{s_1} W(u_1)$$

and:

$$\frac{T}{114.6} = \frac{Q}{s_2} W(u_2)$$

in each of which, respectively, $t_1u_1 = R$, and $t_2u_2 = R$. This pair of simultaneous equations cannot be solved directly for the unknowns, T and R (or S), because T makes a second appearance in $W(u)$. The unique values of T and R that satisfy both equations may be determined, however, by trial and error. S may then be determined from the expression:

$$S = \frac{RT}{1.87r^2}$$

Application

Figures 1 and 2 show the nomographs and transparent plastic arms used to determine T and R by trial and error. One arm in Fig. 1 intersects values of $\frac{Q}{s_1}$, $W(u_1)$, and T that satisfy the expression:

$$\frac{T}{114.6} = \frac{Q}{s_1} W(u_1)$$

The other transparent plastic arm in Fig. 1 intersects values of $\frac{Q}{s_2}$, $W(u_2)$, and T that satisfy the expression:

$$\frac{T}{114.6} = \frac{Q}{s_2} W(u_2)$$

Because T has the same value in both expressions, the two slotted arms are held together by a guide pin that is free to slide along the slotted plastic guide fastened to the T scale. As the guide pin is moved, different values of T are tried in the equations, and different values of $W(u_1)$ and $W(u_2)$ are intersected.

The transparent plastic arms in Fig. 2 intersect values that satisfy the expressions $t_1u_1 = R$ and $t_2u_2 = R$, respectively. Because R has the same value in both expressions, the arms are held together by a guide pin that is free to slide along a slotted plastic guide fastened to the R scale. As the guide pin is moved, different values of R are tried in the equations, and different values of u_1 and u_2—and the corresponding values of $W(u_1)$ and $W(u_2)$—are intersected. In field practice, both guide pins are moved simultaneously, thereby testing different values of T and R in the equations. When the arms intersect the same values of $W(u_1)$ and $W(u_2)$ on both charts, the unique values of T and R that satisfy the equations can be read from the positions of the guide pins.

Several ranges of values are available for the logarithmic scales of the nomographs. In Fig. 1, any one of the pairs of scales labeled I, II, or III can be used for $\frac{Q}{s}$ and $W(u)$, and the T scale remains unchanged. The chart in Fig. 2 can be used for values

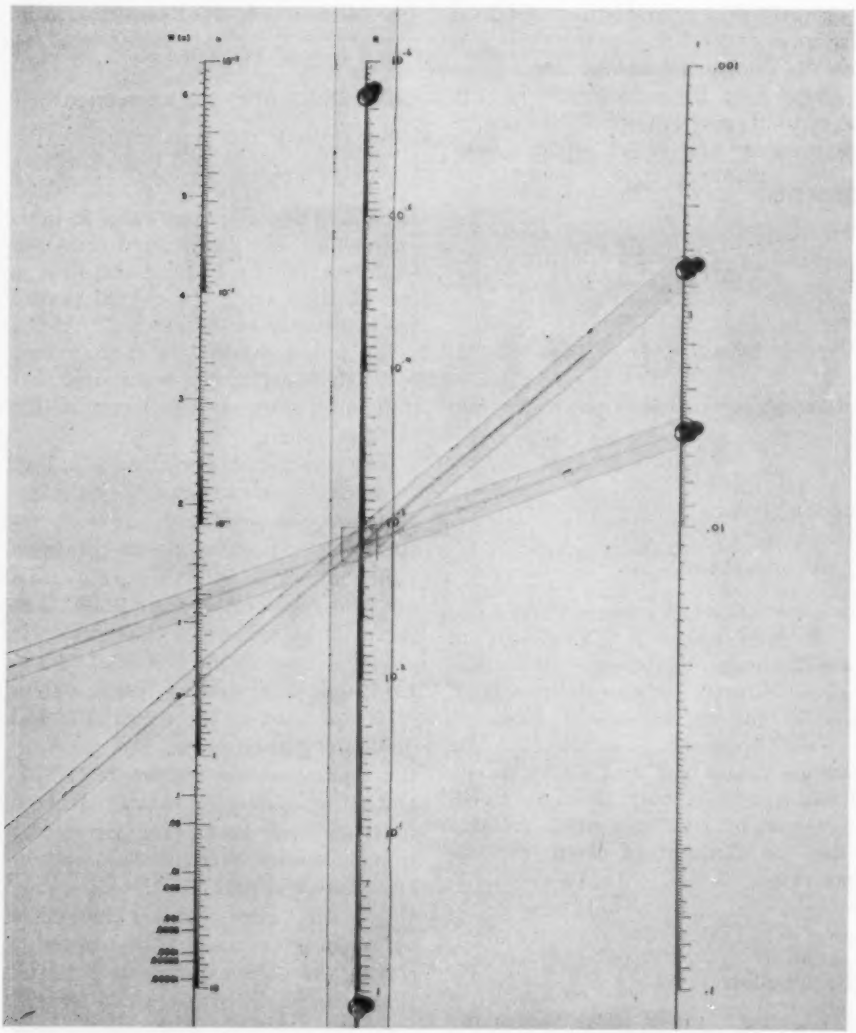

Fig. 2. Nomograph Adapted to the Expression: $tu = R$

of $W(u)$ as large as 6.3. Another chart has been prepared for values of $W(u)$ between 4 and 13. Any range of values of t can be used, and each value of R will then be the product of u and t.

Figures 1 and 2 show the use of the nomographs to solve data from an aquifer test at Seabrook, N. J. Water level measurements were made at an observation well 4 min ($t_1 = 0.00278$ day) and 9 min ($t_2 = 0.00625$ day) after pumping began. The ranges of the t and R scales in Fig. 2 were determined accordingly, and the plastic arms were pinned at the two values

of t. The drawdowns at the two times were 0.66 ft and 1.31 ft, respectively, and the pumping rate was 900 gpm. Therefore, the plastic arms in Fig. 1 were fastened at the values $\frac{Q}{s_1} = 1{,}363$ and $\frac{Q}{s_2} = 687$, the scale labeled II being used. The guide pins are moved along the slots, the arms intersect different values of T and R and the corresponding values of $W(u)$. The figures show that the solution is obtained when the arms intersect $W(u_1) = 0.6$ and $W(u_2) = 1.2$ on both charts. The values $T = 94{,}000$ and $R = 0.0013$ are read from the appropriate scales, and S is computed to be 0.0006 ($r = 330$ ft). This solution compares favorably with the values $T = 97{,}000$ and $S = 0.0003$ determined by the graphical method.

Applications to other tests in New Jersey have shown that values for T and S can be estimated by this method in less than 2 min. In field practice, successive determinations of T and S should be made as water level measurements are obtained.

Construction of Nomographs

The nomographs used in this study are constructed with parallel logarithmic scales. The outer scales may be spaced and positioned in any convenient manner.

The nomograph in Fig. 1 is constructed in the following manner: [1] the T scale is drawn parallel to and half way between the $\frac{Q}{s}$ (left) and $W(u)$ (right) scales; [2] the T scale is traced from logarithmic paper having a 5-in. cycle, and the $\frac{Q}{s}$ and $W(u)$ scales are traced from logarithmic paper having a 10-in. cycle. The cycles are positioned on the T scale by laying a straightedge across the chart. The point of intersection of the straightedge and the T scale has the value obtained by substituting the intersected values of $\frac{Q}{s}$ and $W(u)$ in the relationship:

$$\frac{T}{114.6} = \frac{Q}{s} W(u)$$

The nomograph shown in Fig. 2 is arranged so that the R scale is parallel to the other scales and one-third the distance from the u scale (left) to the t scale (right). The scales in this nomograph are inverted. The t scale is traced from paper having a 10-in. logarithmic cycle, the u scale from paper having a 5-in. cycle, and the R scale from paper having a $3\frac{1}{3}$-in. cycle. The R scale is positioned by laying a straightedge across the chart. The product of the intersected values on the two outer scales determines the intersected values on the R scale. The values of $W(u)$ are obtained from published tables (7).

The nomographs can be relabeled to suit individual preferences. For example, minutes may be used instead of days on the t scale if:

$$S = \frac{RT}{1.87r^2}\left(\frac{1}{1{,}440}\right)$$

The intersection of the straightedge and the R scale remains the product of the intersected values on the other scales.

Limitations

The method presented herein is subject to the same limitations as the nonequilibrium formula. Corrections may be necessary for tidal and barometric effects, for excessive well losses ("screen losses") at the observation well, and for other departures from ideal conditions. Application to data from several New Jersey tests has shown, however, that the method

is sensitive to boundary conditions. The transmissibility coefficients derived from the successive nomographic solutions changed markedly at times when the effects of boundaries were indicated by the graphical methods.

As the rate of drawdown decreases during a test, the values of $\frac{Q}{s}$ derived from successive measurements become so close that the arms cannot be pinned at those values on the same chart. Charts having larger scales may then be used. The authors, however, favor the simpler procedure of using more widely spaced pairs of measurements instead.

Conclusions

Applications to aquifer tests in New Jersey show that, by using a pair of water level measurements, the coefficients of transmissibility and storage can be estimated in less than 2 min by the method described in this paper. The nomographic solutions agree closely with the graphical solutions. The nomographic technique requires less skill for the solution of the Theis nonequilibrium equation than the graphical method. The individual solutions, however, are sensitive to errors of measurement, whereas the graphical solution averages the data as a whole and eliminates erratic measurements. It is believed that this method will prove useful as a rapid field technique to supplement the final graphical solution of data from aquifer tests.

Acknowledgments

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References

1. Theis, C. V. The Relation Between the Lowering of the Piezometric Surface and Rate and Duration of Discharge of a Well Using Ground Water Storage. *Trans. Am. Geophys. Union,* **16**:519 (1935).
2. Brown, Russell H. Selected Procedures for Analyzing Aquifer Test Data. *Jour. AWWA,* **45**:844 (Aug. 1953).
3. Jeffords, Russell M. Private communication.
4. Commons, C. G. Nomograph for Computation of Drawdowns From Theis Nonequilibrium Formula. Texas Board of Water Engrs., Austin, Tex. (1942).
5. Chow, V. T. Drawdown in Artesian Wells Computed by Nomograph. *Civil Eng.,* **21**:48 (1951).
6. Theis, C. V. & Brown, R. H. Use of Slide Rule in Solving Ground Water Problems Involving Application of the Nonequilibrium Formula. US Geol. Survey, Washington, D.C. (1951).
7. Wenzel, L. K. Methods for Determining Permeability of Water-bearing Materials, With Special Reference to Discharging Well Methods. *USGS Water Supply Papers,* No. 887 (1942). p. 192.

Recreational Use of Impounding Reservoirs

Charles A. Dambach

A paper presented on Sep. 22, 1955, at the Ohio Section Meeting, Columbus, Ohio, by Charles A. Dambach, Chief, Natural Resources Inst., Ohio Dept. of Natural Resources, Columbus, Ohio.

FROM cursory reading and observations it might be assumed that multiple use of water reservoirs, particularly for recreational use, is an activity which is grudgingly agreed to by a minority of water works managers under political duress and public clamor. After looking through several AWWA publications and examining the statistics of reservoir use in Ohio, however, the author has become convinced that Ohio water works managers are, generally, strong practitioners of the multiple-use principle of reservoir management.

Situation in Ohio

It is fortunate that such an attitude prevails, particularly in Ohio where recreational waters available for public use are extremely limited. It is not generally understood that, except for the waters of Lake Erie, only one state, Indiana, has less area in lakes per capita than Ohio (*1*). Although reasonably well supplied with rivers and small streams, Ohio's inheritance of natural impoundments aggregates less than 12 sq miles, which is a mere 7,680 acres (*2*). Shermen (*2*) states: "In New England a sheet of water of many square miles is often called a pond. In Ohio, a diminutive body of water is apt to be called a lake. If we define a lake as a body of water free of trees and shrubs for 1 sq mile or more there was none such in Ohio at the advent of the white man. This is in contrast with every surrounding state except West Virginia." To further emphasize the contrast, it might be noted that, in one of its natural lakes (Winnebago), Wisconsin has about one and one half times the water area which is presently available to the public in Ohio. The province of Ontario has a natural water area equal to Ohio's entire surface area.

Economic and Social Aspects

Ohio's recreational use of water is important both socially and economically. During the past year there were more than 10,000,000 visits to state parks alone. Currently, more than a million persons seek relaxation through an evening, day, or weekend of fishing, and thousands more enjoy boating and various kinds of water sports. Only four states consistently lead Ohio in the number of fishing licenses sold, and it is estimated that at least $50,000,000 is spent annually for fishing in Ohio. This is equivalent to more than $500 of business activity for each acre of impounded water in the state.

The booming outdoor recreation business which is reflected in record sales of boats, motors, trailers, camping equipment, fishing tackle, and outdoor clothing is probably symptomatic of more than economic well-being. It in-

dicates the need and desire of many people to find relief in the outdoors from the tensions of their workday jobs and the boredom of extended inactivity resulting from increased efficiency. The need and the demand for this kind of recreation undoubtedly will grow as science makes possible further advances in producing goods with minimal human effort. A 30-hr work week allows at least 30 hr for fishing, and a guaranteed wage may even make it a second profession for many, at least on a temporary basis.

Regardless of personal views on the values of these sociological conditions, the fact is clear that the public may be expected to make ever-increasing demands for recreational use of water. That this demand applies to, and is honored by, water supply reservoir managers is evident across the nation, from Boston's 25,000-acre Quabbin Reservoir to San Diego's El Capitan water storage project. In Ohio, no less than 46 reservoirs supplying waters for domestic purposes are open to recreational use, primarily fishing. Of this number, 22 are of the above-ground type into which water must be pumped from a nearby station, with a combined area of 1,411 acres. Twenty-four are stream impoundments, with a total surface area of 13,720 acres. This represents 15,131 acres, which is over 16 per cent of all the presently impounded inland water available for public recreational purposes and about 80 per cent of the municipal water storage. Financially, it represents $7,500,000 in annual expenditures by the more than 150,000 fishermen who benefit from recreational use of these waters. At current construction costs, it would take at least $30,000,000 to create a comparable area of recreational water, or all of the receipts from fishing licenses issued by the state in the past 20 years.

Inherent Problems

As has been said, it is the rule, rather than the exception, that multiple use of water supply reservoirs is practiced in Ohio. And yet such use is not without its problems.

In a 1948 panel discussion (*3*), Eugene F. Dugger commented that "the enforcement of regulations regarding fishing in water supply reservoirs can be an extremely troublesome and time-consuming operation, which has a tendency to detract from the efficiency of regular water collection and supply operations." It is apparent that the troublesome nature of such use has kept a number of our reservoirs out of bounds to the public.

In the same discussion (*3*), Richard E. Bonyun expressed the view that the time has passed ". . . when the water purveyor could adopt a 'take it or leave it' policy or establish restrictions without good and substantial reasons for them." "It is far better," he continued, "to designate, equip, and supervise the use of certain areas, or to permit fishing on a limited and organized basis, than to be constantly fighting with the public to enforce a no-fishing and no-picnicking policy, which everyone knows cannot be completely enforced."

It is obviously important that officials concerned with recreation and the public, as well as those responsible for public water supplies, understand the problems inherent in multiple use of water reservoirs.

Unquestionably, the problem of first consideration is to establish an adequate supply of water which can, by appropriate treatment, be delivered to the consumer in a clean, healthful, and

potable condition. Any other use of stored water must of necessity be secondary to this purpose.

It is now appropriate to inquire if such recreational use of water as boating and fishing is inimical to domestic water use. It is also appropriate to inquire if water supply reservoirs, under normal use, provide high-quality recreation. The author's observations lead to the conclusion that both uses are compatible and in the best public interest under appropriate regulations. Were it possible to obtain storage waters from wholly uncontaminated sources, there might be room for argument on this point, but it is to be noted that, under Ohio conditions, virtually all surface water storage is drawn from streams which are frequented by the public right up to the headwaters of the reservoirs themselves. Most of these streams carry a steady load of silt from eroding farm lands, washings from road ditches, and effluent from the bordering communities and outlying residences. These conditions necessitate treatment of the stored water before it can safely be delivered to the consumer. Unless recreational use introduces adverse materials not already present in the contributing waters, or materially adds to the treatment costs, such use is not inconsistent with the primary purpose of water reservoirs.

Although this view appears to be biologically sound, it may not meet with local public acceptance because of prejudice or lack of information. It is not difficult to visualize public concern over pollution of stored water by recreational users if the public is not fully aware of the entire picture. On this subject, Gerald E. Arnold (*3*) has said that "comparative studies of the pollution of open and closed reservoirs have disclosed no indication of increased pollution in those reservoirs that are open," and he "fails to see how the water works industry is justified in prohibiting recreational activities on water supply reservoirs so long as such activities are properly controlled and the water is adequately treated."

It should be noted that both advocates and opponents of recreational use of public water supplies recognize the need for regulated use. Regulations in this situation imply not only rules and their enforcement, but public-use facilities to which the rules apply. Depending on the degree of public control necessary, this may involve fire protection, fencing, gates, parking areas, wells, toilets, picnic tables, boat ramps, docks, motor regulations, or even a boat concession.

Basis for Controversy

The author suspects that much of the resentment against multiple use is associated with regulating the public and servicing the facilities necessary for recreational use of reservoir areas. This, he believes, is a greater deterrent to such use than concern over impairment of water quality. Availability of funds for these purposes may also be a deterrent, particularly where water revenues are earmarked exclusively for water supply purposes. The author appreciates this problem, and he is acutely aware of a legal necessity for expending hunting- and fishing-license funds only for hunting and fishing purposes.

Neither the money problem nor the public-control problem should interfere with multiple use of reservoir areas, however, because, in many, if not most, situations, recreational agencies equipped to do the job are looking for just such places to set up shop and go to work. Nevertheless, it is prob-

ably safe to assume that most municipal water departments would prefer to keep complete control in their hands. This is understandable for proprietary, psychological, and management reasons. Lacking necessary funds or authority, however, it would seem that a water management official would first seek assistance from the recreational agency of the municipality he serves. Assistance from other agencies may also be forthcoming. In certain situations, the Wildlife Division of the Ohio Department of Natural Resources has entered the picture, but only to the extent that hunting- and fishing-license buyers were benefited, and only where local agencies were unable to provide the minimal requirements for public use.

Ideally, it would seem best that new water storage projects be designed so that desirable recreational features can be incorporated into the basic plan. This should avoid many of the problems such as inadequate land for public use and lack of access, both common to projects where only water supply was considered. An example of good planning for such multiple use is to be found in the water supply reservoir built by the city of Alliance, on Deer Creek, in Stark County, Ohio, where the city, the US Army Corps of Engineers, and the division of wildlife have joined forces to provide not only an adequate water supply for the city but public hunting, fishing, boating, and picnicking for its citizens, as well. Another example is to be found in the plan adopted by Columbus, Ohio, for permitting public fishing and other recreational use of Hoover Reservoir. The recreational features of this project were developed by the city recreation department. The fishing management plans were developed by the state division of wildlife for the city water department. This project gives promise of providing one of the finest fishing areas in the state and creating related business activity aggregating over $1,000,000 a year.

Compatible Interests

One aspect of this problem which should be considered is the compatibility of water management for domestic consumption with water management for recreational use. They cannot, of course, be completely compatible. The necessary drawdown during periods of low flow—which is generally not harmful, and perhaps is even beneficial to fish production—sometimes creates unsightly conditions and difficult access problems. The necessary removal of trees and cropping of vegetation eliminates favored habitat for some desirable fish and thus affects places where the fishermen may find them. Frequent treatment of water with algicides may cause major interruptions in the food chain of fish and the practice of planting trees, particularly pines, on the water's edge creates both a fire hazard and a nightmare of tangled lines to the person attempting to cast from shore. The author's personal conviction is that the planting of pines has been overdone in many situations, including the watersheds of some Ohio reservoirs. They pose a much greater fire hazard than native hardwoods and are not the great conservers of water which so many people believe them to be. A neat sward of grass is much less of a hazard and is equally, if not more, effective for soil and water conservation. It also interferes less with human use of the area.

The conditions described here add up to recreation of a somewhat lower quality than might be obtained on a

comparable area managed solely for recreational purposes. The differences are not of sufficient significance, however, to warrant any changes from good water supply management practice or to reduce their value for recreational use. The public should realize this and consider recreational use to be a byproduct of impounded water supply which must be subordinate to such use but not excluded by it.

Conclusions

It has not been possible in this article to treat all aspects of the problem, nor does the author consider himself competent to do so. Certain conclusions, however, appear to be justified from the writer's experience, observations, and inquiries. They are as follows:

1. Water area for recreational use, particularly in states like Ohio, is in short supply and great demand.

2. Creation of water areas exclusively for recreational purposes is extremely costly and, except to a limited degree, is beyond the financial ability of most agencies concerned with this problem.

3. Use of reservoirs for both recreation and water supply appears feasible under appropriate regulations. Such multiple use contributes substantially to lowered costs of government services related to these uses.

4. As a general rule, costs of recreational use of water supply reservoirs should be borne by the benefiting public. Often, both the recreationist and the water user is the same person. The mode of meeting these costs should be designed to distribute the burden fairly and in keeping with applicable legislation.

5. Agencies in charge of water supplies should not reject the possibility of recreational use of waters because of lack of interest, prejudice, or inadequacy of funds and authority. They should rather invite the shouldering of this responsibility by agencies equipped for that purpose.

6. A surprisingly large proportion of the water supply managers, particularly in Ohio, appear to be exponents of a philosophy that says "you can enjoy your water and drink it too." A highly significant proportion of the available recreational waters is provided as a byproduct of water supply storage. There remain, however, thousands of acres of water area which are not being put to their fullest use.

References

1. Statistical Abstract of the United States, 1954. Bureau of the Census, US Dept. of Commerce. Washington, D.C. p. 10.
2. SHERMEN, C. E. Ohio Stream Flow, Part I. *Ohio State Univ. Studies, Engr. Exp. Sta. Bull. 73*, **1**:7 (Sept. 1932).
3. BONYUN, RICHARD E., ET AL. Public Use of Reservoir Lands and Waters. *Jour. AWWA*, **40**:945 (Sep. 1948).

Discussion

Merrill L. Riehl

Supt. of Water Purif., Mahoning Valley San. Dist., Youngstown, Ohio.

In speaking of recreational use of domestic water supply reservoirs, the discusser disagrees with the author as to many of his general statements. Having been closely involved with water treatment plants which process water from supplies with both protected use and practically unrestricted recreational use, the discusser has seen

only disadvantages in recreational use of the reservoir. The use of reservoirs for recreational purposes may, in theory, seem an obvious asset. The other side of the picture, however, should be given serious thought by water works men.

This discusser believes that most, if not all, of the water supply managers who "appear to be exponents of the philosophy that you can enjoy your water and drink it too" merely do *appear* to be exponents, and that their hands are tied by one means or another in this matter. From talks with many water purification men on this subject, the discusser has found that everyone who had been contacted felt much as he did, and that they, personally, would much prefer to keep the reservoirs protected and reserved for water supply.

Public Opinion

It is possible that men working with a privately owned water supply may look at this problem from a slightly different viewpoint. They are in a position to make sufficient charges for recreational use to pay all the additional expense of policing and enforcing regulations day and night in an attempt to minimize pollution, and still show a profit to the stockholders. Publicly owned water supplies, however, cannot carry such charges, since the opinion that the "public should have free use of public property" prevents the program from paying its way.

There is no question that it is difficult to overcome the public apathy to the need for an adequate, safe, and potable water supply. In order to get the voters to approve the expenditures for such needs, the water department all too often must secure every type of cooperation possible. It is here that recreation-minded groups are often asked to help, and this, of course, leaves the water departments obligated to them. The water department, in other words, may be forced to take half a loaf or else it would have none at all.

Merely because these are the existing facts, however, water purification men have no reason to cease vigilance and throw up their hands in despair. If more of them would express their views, it would help others in their battle to have the best supply possible. Water works men owe the public one thing, and that is an adequate, safe, and potable supply. This obligation must be fulfilled at all costs. One of the best means is to safeguard the raw supply. The situation is comparable to the present views on milk sanitation. After pasteurization had proved to be effective, the tendency was to pay very little attention to the sanitary condition under which the raw milk was produced. Almost any milk could be made to be safe. Today, however, the picture is changed. Every one is aware of the carefully controlled conditions of sanitary practice that are absolutely imperative at the dairy barns. Pasteurization has become only an additional factor of safety.

Water supply interests are presently passing the stage where there is no longer a desire to rely entirely on treatment, particularly chlorination, to protect water supply. Water works men want to have the raw water just as perfect as it can possibly be, so that treatment and chlorination will become additional factors for safety and not the total solution. This ideal state is far away, but opening reservoirs to recreational use certainly is a step backward, not forward.

Disadvantages

Before any water department official compromises himself to settle for "half a loaf" he should consider the following additional factors which he must face with recreational use:

1. The pollution load will be greater. It has been stated that practically all public water courses are polluted anyhow, and recreational use would add very little to the load. Even the smallest causes of pollution cannot be ignored, however, and every attempt should be made to reduce, instead of increase, the load. Also, if the waters are heavily polluted, there is reason to question their suitability for recreational use, and, if they are not heavily loaded, the additional load may result in a dangerous condition.

2. The water is more difficult to treat, resulting in greater cost for chemicals to assure proper taste and odor control. Additional screening procedures would also be required.

3. The public is entitled to, and should have, a reservoir that is not littered and repulsive to the eye. Recreational use makes this almost impracticable, even with constant policing.

4. The additional costs of policing the grounds, maintaining facilities such as picnic tables, shelters, wells, rest rooms, and boat ramps are appreciable. If the utility assumes this cost, the consumer has to pay for it. If part of the costs are assumed by recreational groups, the utility then compromises on its control of the reservoir.

5. Public use creates fire hazards for the shore plantings which are so important in minimizing silting of the reservoir. The fire hazard is even greater where evergreens are planted completely around the shore line for the purpose of screening out deciduous leaves, which are troublesome in taste, odor, and color control.

6. Public use is not compatible with heavy evergreen planting of the bordering area. This practice, which is followed by many water works men, has been found to provide added protection to both the reservoir and the water supply in various ways. The evergreen planting, with its resultant pine needle cushion, gives better sheet erosion control, causes retarded runoff of snow and ice, helps sustain stream flow, rehabilitates springs, and reduces losses due to transpiration.

7. The utility is subject to large claims for accidents occurring on the grounds, and must either carry broad insurance or take a chance on expensive lawsuits.

8. Demands, contrary to the best interests of the water supply, will be made by various groups wishing to increase the recreational value. Requested may be such changes as limited planting of short line, restrictions on use of algicides in the reservoir, and maintenance of constant level.

9. Because of the greater number of potential offenders on the grounds, limited recreational use is more difficult to enforce than no recreational use at all. Unlimited recreational use, with no regulatory control, would seem unthinkable because of the pollution hazard.

10. Recreational privileges bring a demand for cottage sites, and this should not be tolerated because of the much greater pollution load. If this is not granted, it will be a source of constant pressure from certain individuals with political prestige. Also, pressure will

be brought to bear for trailer parking and tenting privileges on the reservoir grounds.

11. Chances for pollution or contamination by sabotage are greatly increased by public access to the water supply.

Conclusion

Water purification men must never forget their obligation to *all* the consumers, in spite of the fact that they get little or no expression of appreciation for their vigilance. Ideals must not be compromised by other agencies, which may be very convincing in their arguments to further their own specific desires, and which have almost unlimited capacity to gain so-called "public" support for their demands. Such propositions must be clearly evaluated. It is easy to see how pressure from those who speak loudly can force water purification men to take the path of least resistance and overlook the welfare of the consumers who buy the water and use it to maintain life and health. It must be remembered, therefore, that opening the reservoirs to the public can make it a little bit easier for that "impossible" epidemic to strike, and if it does, it is the water works men, not the recreational users, who are responsible to the consumers and to the public-health officials.

Recording Instrumentation in Water Treatment Plants

Oscar Gullans

A paper presented on Jun. 14, 1955, at the Annual Conference, Chicago, Ill., by Oscar Gullans, Chief Water Chem. Engr., South Dist. Filtration Plant, Chicago, Ill.

THE operation of Chicago's South District Filtration Plant, which is presently considered the world's largest water treatment plant, depends to a great extent on the 352 primary measuring and recording units with which the plant is equipped. These instruments are essential in the control of water basin and tank levels, pumpage rates, and chemical dosage; in the study of operating efficiency; and in preparing consolidated operating and technical reports. They provide a graphic, up-to-the-minute record of operating phases and frequently reveal unusual conditions which can be quickly traced and corrected. They gather information automatically and continuously 24 hr a day without the presence of a human operator. In short, they supply the data which lead to better service, greater safety, and more economical operation.

In the South District plant, recording instruments are required to operate under conditions of dampness, vibration, extremes of heat and cold, and in corrosive atmosphere; yet, as permanent equipment, they are expected to last for a period comparable to that of the heavy apparatus with which they are used. Accordingly, the instruments used are required to have maximum practical accuracy and flexibility in combination with ruggedness and simplicity.

In a large water plant it is essential that the recording units of certain critical instruments be located where they can be observed continuously by the operating personnel concerned. At the South District plant, a centrally located control panel equipped with 30 automatic recorders, as shown in Fig. 1, is used. These recording units are actuated by pneumatic or electric integrating and recording transmitters located at each important phase in the plant's operation. The control panel is manned by competent engineers 24 hr a day and serves as the nerve center for all plant operations.

All essential recording instruments can operate on emergency power. Whenever the "house" current is interrupted, the emergency generator and storage battery circuits automatically cut in to keep the instruments in operation. This provision is particularly important in the control of water levels, chemical feeds, and residual chlorine. Although only a few of the many recorders in use throughout the plant will be discussed here, most of those critical instruments on the control panel, which might be called the operating group, will be described.

Water Level Recorders

Among the most essential instrument groups on the panel is the set of water level recorders. The transmit-

ters of these are actuated by pneumatic equipment with impulses transmitted electrically to the recorder. Most of the transmitters require a constant source of compressed air as well as electricity; some, however, are located to permit operation by direct water pressure from the tank or basin. The control of pumpage rates and water levels at this plant assumes greater importance when it is noted that summer peak loads require nearly twice the normal rated capacity. Since no elevated storage is provided in the system, it is necessary that production equal consumption at all times. Accordingly, the plant operates within extremely close water level tolerances, and a single wrong move can cause the filtered-water reservoir to overflow or flood out other portions of the plant.

Eight essential recorders (indicating the water levels of the pump suction header, pump discharge header, settling basins, and filtered-water reservoirs) supply the control engineer with a continuous visual record of the status of each unit. These recorders indicate not only when it is necessary to adjust pumpage rates, but also any unusual condition that may develop. As a typical example: At 8 PM on Jul. 31, 1949, the control engineer observed a sudden rise—at the rate of 1 ft in 10 min—in the level of the filtered-water reservoir, as indicated by the elevation gage shown in Fig. 2. (The reservoir is operated within limits of 1½ ft of maximum or minimum levels.) A hurried call to the filter operators revealed that the compressed-air supply had apparently failed and that the filters under automatic control were completely open. The filtration engineer and filter operators succeeded in shutting off those filters quickly, and had matters under control by the time the reservoir reached a level within 6 in. of overflowing. The urgency of the accident was compounded by the fact that it happened at a time when the plant was supplying water at nearly the peak rate.

The experience gained from this mishap led to swift remedial action. An auxiliary compressed-air tank of 100 cu ft capacity was installed to serve each group of twenty filters. These tanks normally function as part of the regular compressed-air system, which operates at 100 psi; if the pressure drops below 80 psi an automatic valve closes the supply from the compressor and retains the pressure in the tanks until the supply pressure is again normal. The auxiliary air thus provided is sufficient to operate filter controls for a period of 2 hr or longer, which is time enough to set up the manual filter controls, or to place a small emergency steam-driven compressor in service on the line. The plant also possesses a portable gasoline-powered air compressor which can be connected to the compressed-air line at several points.

A second precautionary measure was to initiate regular periodic tests of all filter controls. Normally, if air pressure fails, the filter controls are designed to hold the filter at its current operating rate, rather than to permit the effluent control valve to open wide. At the time of the near-flood condition, however, these controls failed to operate on 75 per cent of the filters, due to lack of proper maintenance. It is now standard practice for an operator to trip these controls at least once each week in addition to current preventive maintenance, to make sure that they are operating properly. Subsequent tests of the compressed-air system indicated the filter controls to be running perfectly.

Fig. 1. Central Control Panel, South District Filtration Plant

The panel, located in the control engineer's office, is equipped with 30 automatic recording units connected by electric and pneumatic transmitters to instruments at each important step in the plant's operations.

As an additional safeguard, red warning lights have been installed on the control panel beside each recorder; these turn on automatically as soon as the water level comes within half a foot of the maximum safe level. A warning bell rings when the pressure of the plant's compressed-air system falls below 80 psi.

Further difficulty was experienced with these transmitters when they were equipped with oil bubblers used as air flow indicators. Some oil eventually reached the contact switches, necessitating frequent maintenance. In addition, the small needle valves controlling the air supply frequently became fouled. These conditions were partially corrected by replacing the oil bubbler cups with small rotameter-type air flow indicators, using a light plastic ball instead of a rotor. The needle valves on the air supply line were replaced by a larger type of regulating valve, to compensate for increased wear. This type of air flow indicator has given excellent service for many years, and requires little or no maintenance.

A second maintenance factor, which applies to all pneumatic controls or air-operated instruments, is the need for clean, dry compressed air. This was provided by the installation of an electric dryer and an oil filter unit. Though the filter unit was originally designed for glass wool filter pads, these have since been replaced with cellulose fiber pads, which are more efficient in removing fine particles of oil carried with the compressed air. All these changes have reduced maintenance on the water level recorders by 75 per cent.

Residual Chlorine Recorders

Another important set of recording instruments is the group of seven residual chlorine recorders. These are also located on the central control panel, where they are under continuous observation by the control engineer. All deviations or deflections of the re-

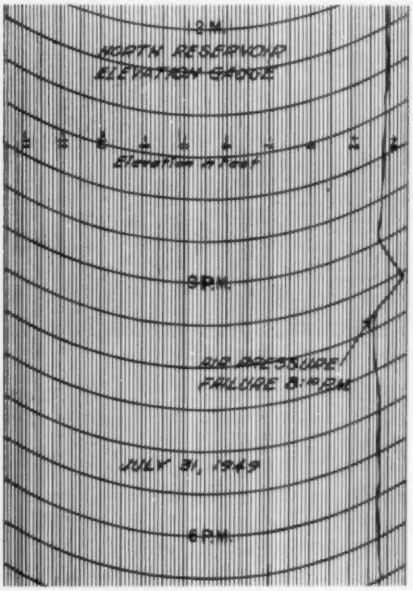

Fig. 2. Water Level Recorder Chart

The chart shows surface elevation changes in the North Filtered-Water Reservoir on Jul. 31, 1949. The major deflection indicates a sudden rise.

corders, including those caused by normal dosage changes, are immediately reflected on the recording charts. This kind of surveillance assures adequate chlorination of the water in its progress through the plant, and particularly at the plant outlet. The charts in Fig. 3 present a graphic illustration of a series of typical changes.

Chart 3*a* indicates a sharp drop in chlorine feed between 11:00 and 11:30 AM. The recorder is connected to a sampling line from the point at which the water enters the first mixing basin, approximately 4 min after the chlorine has been added.

Chart 3*b* indicates the chlorine residual at the entrance to the settling basin, 30 min later. On this chart, it will be observed, striking deviations caused by the sharp drop in chlorine feed have been tempered somewhat by dilution.

Chart 3*c* is from the residual chlorine recorder at the end of the settling basin, approximately 1½ hr later. Here the dip in the curve is still quite pronounced.

Chart 3*d* is from the recording unit which indicates the chlorine residual at the entrance to the filtered water reservoir. At this point the residual had only dropped to 0.6 ppm, which was not below the minimum standard. It was not necessary, therefore, to apply additional chlorine at the outlet shaft.

There have been numerous occasions when such an interruption in the chlorine feed, immediately indicated on the recorder charts, resulted in effective remedial action before the water left the plant. Additional chlorine may be applied at the filtered-water header (the entrance to the filtered-water reservoir), and at the outlet shaft, which is the final point of chlorination. In any case, if the recorder chart indicates an approach to a minimum residual at the outlet shaft, additional chlorine can be applied at that point at a few minutes notice. Thus, the recorder charts act as "watchdogs" for the entire chlorination process. Because of the satisfactory operation of these recorders, the same type has been installed in the pumping stations, both in the area supplied by the filtration plant, and in the

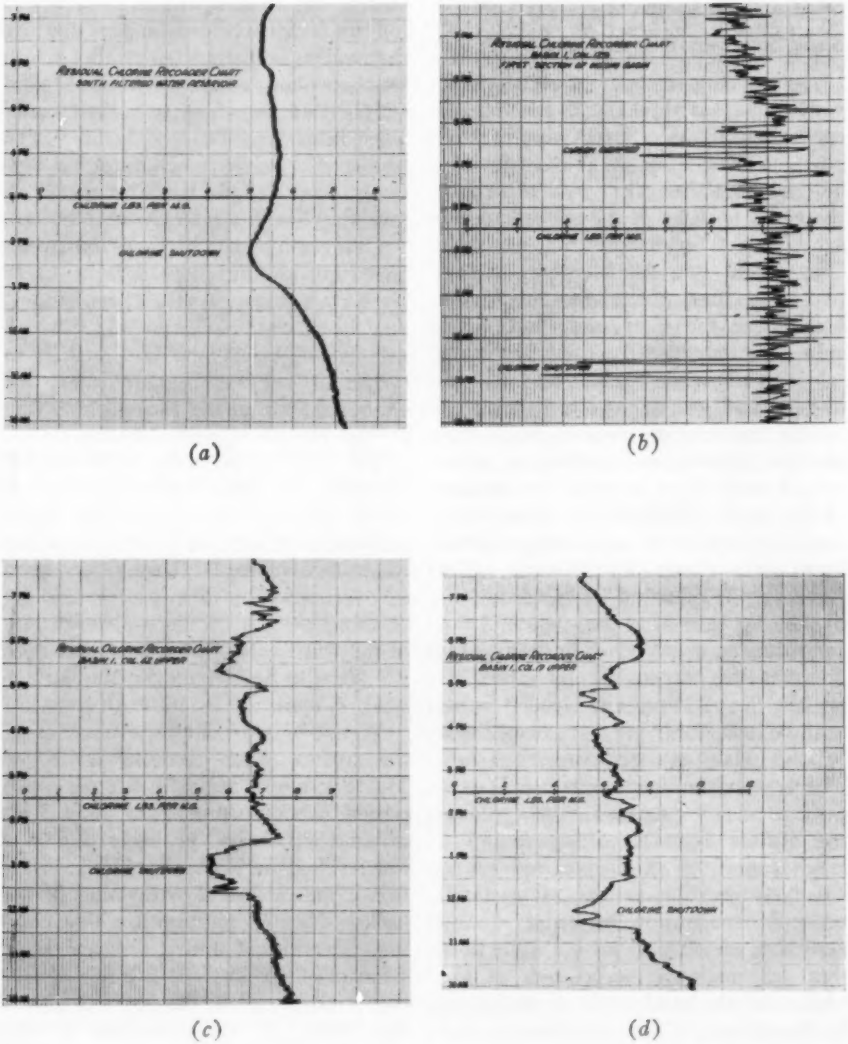

Fig. 3. Residual Chlorine Recorder Charts

The charts were made by recording instruments connected to sampling lines at various points in the plant's operations. Chart a *is from the point at which water enters first mixing basin; Chart* b *from entrance to the settling basin; Chart* c *from output end of the settling basin; Chart* d *from entrance to the filtered water reservoir.*

areas in which chlorination is performed at the pumping station itself.

Sand Expansion Recorders

A recording instrument seen in few water plants is the sand expansion recorder for filters. These air-operated gages provide a simple and instantaneous means of indicating and recording the exact position of the surface of the sand in a filter bed during washing. The system consists essentially of two parts—the transmitter, mounted on a beam over the filter bed; and a receiver, mounted on the filter operating table, in the same cabinet as the loss-of-head and rate-of-flow recorder.

The transmitter consists of a diaphragm housing, supporting a lightweight cone which rests on the surface of the sand. Lightweight tubing connects the cone with a counterweighted beam arm above water level. The beam arm is actuated by the tendency of the cone to float at the surface of the sand during washing. The beam arm operates the transmitter by means of an air flapper and air bleeder valve with bellows. Air pressure from these bellows also actuates the receivers. The transmitter is primarily a heavy-duty precision pressure gage containing a flow actuator, linkages, and a chart calibrated in the desired units. (It is interesting to note that sand, when in suspension in water, exerts sufficient pressure to raise a light float that will maintain a position at the surface of the sand when expanded in backwashing.) The instruments can be easily cleaned, and may be adjusted by manipulation of the counterweights and linkages.

In operating the filters at the South District plant it is attempted to maintain a backwash rate which will produce a sand expansion of 3½–4 in. This may seem somewhat low, but with 0.65-mm sand, experience has shown that this expansion is sufficient for thorough backwashing. Because the water temperature at the South District plant varies between 32 and 72°F, it is necessary to adjust backwash rates accordingly. At 32°F, the backwash rate fo reach filter is normally 25–26 mgd, while at 72°F as much as 34–35 mgd may be required.

Observation of the sand expansion chart quickly indicates current backwash conditions. As the chart is operated by an automatic time clock which rotates only while the backwash is in operation, the recorder indicates the exact duration of the backwash as well as the record of sand expansion. A single chart is normally sufficient for recording the filter washes for 7 days. With this type of control the chart indicates any unusual conditions which might be detrimental to the filters, such as overexpansion of a sand bed, short washing period, or incomplete closing of the wash valve. The float unit does not seem to be affected by the surface wash system.

Figure 4 is a composite chart from the surface wash recorder on Filter 31. Section 1 indicates a long wash period (about 6 min) with only 3 in. of sand expansion, probably due to a low level of the wash-water tank. Section 2 indicates a slow opening of the backwash valve; Section 3, a slow closing. Sections 4 and 7 are typical of a normal filter wash of 2–3 min. Section 5 indicates that the operator closed the backwash valve instead of the surface-wash valve. Section 6 is a typical indication of the start of backwashing on another filter while the wash is still in progress on the filter to which the chart applies.

These recorders require very little maintenance. An occasional oiling and cleaning of the linkages serves to keep

them in smooth operating condition. As clean dry air is used in the South District plant, the input control orifice seldom needs to be cleaned. Flexible rubber air connections require occasional replacements, and the South District plant considers synthetic tubing more satisfactory for its purposes.* Installation of these sand expansion recorders on each of the plant's filters has proved a sound investment.

Filter Controls

The filter loss-of-head and rate-of-flow recorders are standard units equipped with air transmitters. The rate of flow is measured by the differential pressure from the venturi tube, which actuates the diaphragm chamber to one side of the transmitter unit. Compressed air at a reduced pressure (2½–15 psi) operates the transmitter through an input-restricting orifice. The variable pressures are in turn transmitted to the recording chart on the filter operating table. The loss of head is measured by static pressure maintained across the upper and effluent section of the filter.

Within 2 years after these instruments were installed it was necessary to replace all the steel attachments with stainless steel hardware, because of rusting and corrosion due to dampness in the air. This was also required on the transmitter units on the loss-of-head and rate-of-flow recorders. The plastic mercury wells on these units began to crack after about 5 years of operation. This is believed to be due to the method of attaching the wells to the holders; and the screw locks presently used for that purpose are being replaced by metal ring clamps.

* Tygon, a brand of synthetic corrosion-resisting tubing manufactured by US Stoneware Co., Akron, Ohio, is used.

Dehumidification equipment was installed in the filter pipe galleries in 1950 to reduce exterior corrosion of instruments and filter equipment. Humidity is now maintained at less than 50 per cent at all times, regardless of temperature, and condensation has been completely eliminated. It is estimated that this equipment has already more than paid for itself in reduced maintenance costs.

The air supply used in these air-operated instruments should be absolutely clean and without free moisture. The importance of this is evident from the fact that the input-restricting orifice measures only 0.007 in. in diameter. Pressure in excess of 5 psi above the required operating level should be available.

For small installations, if there is no air available from a compressed-air header, a small compressor of the diaphragm type works very well, with adequate controls. The supply should first be passed through an effective air cleaner to remove dirt and moisture, then through a reliable pressure-reducing valve and a sufficient length of metal tubing to allow the expanded air to assume room temperature before entering the instruments.

For larger installations, in which the air supply comes from a compressed-air main, it is best to feed the air through a pressure tank which can serve to collect oil and water globules or even scale accumulated in the air main. An additional air dryer and cleaner should be used in the line after pressure reduction. When the header supply fluctuates in pressure, pulsation may be eliminated by using two pressure-reducing valves in series, setting the first valve midway between the high and low pressures. Copper refrigeration tubing is recommended for most piping connections as it is flexi-

ble, free of internal scaling, and less subject to leaks. Only globe or globe needle valves packed for air service should be used.

Flowmeters

Another important recording instrument of the flowmeter type is the propeller-type indicator-totalizer-recorder meter located in the outlet shaft. This outlet meter is in continuous function recording the actual water output to the South District pumping stations. The water velocity actuates a six-bladed propeller, 33 in. in diameter, which is mounted in the center of a 16-ft diameter shaft, 82 ft below the surface. The propeller drives an enclosed vertical shaft to the transmitter unit. The electric impulses are carried to a selsyn motor linked to a differential mechanism which operates the indicating and recording charts in the control room, half a mile distant. Impulses are also carried through the motor circuit to a calibrated totalizer in the recording unit. There is a totalizer at the transmitter, as well, which is geared directly to the propeller shaft and can be used to check the accuracy of the electrical transmitter and recorders. These instruments have given excellent service, and are accurate within 1.0 per cent, which is considered unusually good for such an installation.

Other instruments important to plant operations are the electric-load meter-recorders, wash water pumpage and tank level recorders, pH recorders, and the radioactivity monitor recorder. In a large water plant, it is necessary to maintain close control of electric power loads for the control of peak power-demand rates and lighting economy. Recording of filter wash water requirements is essential: including water for other plant requirements, the South District plant uses an average of 6.4 mgd. The pH recorders are necessary for corrosion control. The radioactivity monitor is equipped with a continuous recorder set up to indicate any such contamination as a part of the plant's civil defense activity.

In order to keep pace with modern improvements, the plant has purchased a magnetic flowmeter-recorder to fit a 20-in. pipeline. This instrument consists of a flow transmitter connected by electric cable to a dynalog receiver. Pneumatic or electric control as well as recorder or alarm accessories may be added to the dynalog instrument in the usual manner. An important advantage of this unit is its freedom from a number of the limitations of meters of the differential-pressure or restricted-area type. The pressure drop through the magnetic flowmeter tube is the same as it would be through a length of standard pipe, as there is nothing in the tube to obstruct the flow. By adjusting the instrument to read center scale for zero flow conditions, it will measure flow in either direction. The unit will be used for experimental purposes to determine its adaptability to larger pipe sizes. A unit of the same type has been used for some time for measuring flow rates on smaller lines (of up to 8-in. diameter). If this combination of flowmeter and recorder proves to be accurate at constant and variable flow rates, it may serve to eliminate some problems now encountered in operating high-rate filters with restricted effluent lines.

Maintenance

Maintenance of all recording instruments is performed by a full-time electrician-mechanic who is specially trained for this service. There is, in

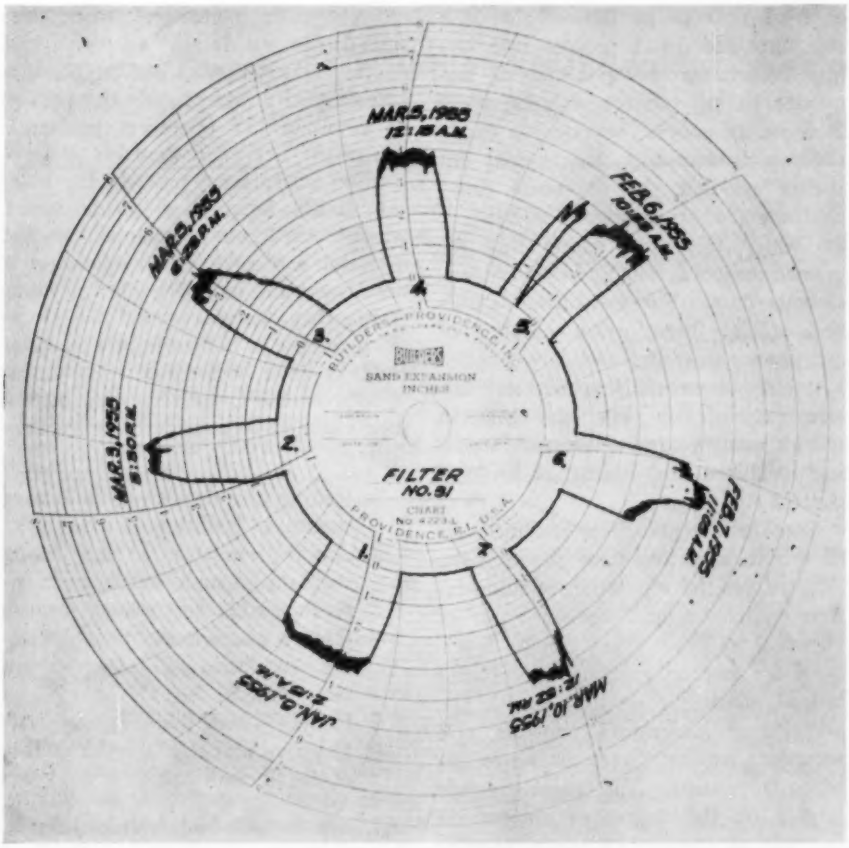

Fig. 4. Composite Chart From Sand Expansion Recorder

The numbered sections were each derived from a separate day's record from the surface wash unit on Filter 31. The chart is operated by an automatic time clock which rotates only during backwash.

addition, a team of technical engineers, whose primary function is to calibrate instruments and detect malfunctions. A preventive maintenance schedule is set up for all instruments, and all necessary repairs are recorded. This schedule assures inspection and maintenance of each instrument at specific intervals and has resulted in good performance with minimum replacements.

Automatic Controls

A look into the future shows that rapid advance is being made in adapting certain industrial instruments for water works use. Instrument manufacturers have developed automatic controls that require little attention, yet are rugged and reasonably foolproof. Wherever a specific action must be repeated for every increment

of total flow or of the weight of a substance added to a process, integrating flowmeters using automatic sequence timing controls can be used. It must, of course, be possible to do the job mechanically, but it does not matter whether the substance flows continuously or is added in batches. In water treatment plants this sequence control is usually based on continuous flow. For measuring liquids and solids, there are a number of continuous-weighing and flow control systems commercially available. Instruments of this type have been in use for many years on automatic washing machines and industrial process-control equipment.

Some of the principles and methods of automatic control have already been adapted for the regulation of fluoridation equipment and similar types of chemical feeders. Many can be developed for use on existing equipment: indeed, electronic devices permit the addition of integrators, controls, and recorders without direct contact to existing equipment. The choice depends largely on the degree of automation desired, as continuous timer systems can be made either partially or completely automatic. Combinations of instruments and remote control devices now available are able (with sequence timing control) to perform the complete operation of shutting down, washing, and returning to service a rapid sand filter without human attention, recording all operations in the process.

Such instrumentation, when designed for maximum accuracy and flexibility together with ruggedness and simplicity, can provide the answer to a number of operating problems. The many automatic controls and recording instruments now on the market should be studied to determine whether they can be adapted for use in water works. Human operation is not always the most reliable: in water plants that operate around the clock, the incidence of human failure on night shifts is quite high. Accordingly, automatic controls and recording instruments should be considered when they will:

1. Reduce the danger of failure of treatment facilities
2. Aid the operators in performing their duties more efficiently
3. Reduce labor requirements
4. Assure management that operating procedures will be carried out as intended
5. Reduce plant maintenance costs
6. Improve and stabilize the quality of the filtered water.

Under the able leadership of John R. Baylis, Engineer of Water Purification, there are now seven experimental projects in progress at the South District Filtration Plant. Instrumentation plays an important part in many of these projects, and, as surveillance tests are completed and minor defects are discovered and removed, it is hoped they will prove of value to the water works industry.

Ultimate Disposal of Radioactive Reactor Wastes in the Oceans

Charles E. Renn

A paper presented on Dec. 15, 1955, sponsored by the AWWA, at the Engineers Joint Council's Nuclear Eng. and Science Congress, Cleveland, Ohio, by Charles E. Renn, Prof. of San. Eng., Johns Hopkins Univ., Baltimore, Md.

FOR various periods over the past 2½ years, a study group from the Johns Hopkins University Department of Sanitary Engineering and Water Resources has been investigating the practicability and cost of sea disposal of large quantities of high-level reactor wastes. This investigation has been part of a more comprehensive study of future disposal problems sponsored in the department by the Reactor Engineering Division of the AEC.

Preparations

In preparing the present article, attempts were made to determine the validity of the department's relatively limited work with sea-dumping operations and to see what features of those experiences might be projected to the design of reactor scale operations. Visits were made to the principal installations on the Atlantic and Pacific coasts. Various dumping practices were discussed with responsible officers of AEC contract works and opinions of leading physical oceanographers, marine geologists, and ecologists were sought. This survey indicated that only casual use was being made of oceanographic information and that most existing practices had developed as practical expedients to take advantage of various local conditions. The methods of disposal used for low-level wastes were clearly inapplicable to the kinds of wastes anticipated from a developing reactor power economy. It became clear, also, that oceanographers were unaware of the waste problems associated with the future fission industry.

In the late summer of 1954 a conference on ocean disposal of radioactive and fission wastes was arranged by the department's study group, through the cooperation of the Woods Hole Oceanographic Institution. At this meeting, specialists from the AEC and contract projects presented information on the properties and potential quantities of wastes to a group of leading oceanographers from the eastern Atlantic area.

After an exchange of minutes and other material, a memorandum was prepared representing the problems projected by waste engineers and the comments of oceanographers. This was sent to the principals for study.

On Jun. 22 and 23, 1955, a second conference for a more informed examination of the problem was held at the Woods Hole Oceanographic Institution. The participants included most of the leading physical and chemical oceanographers, marine geologists, and ecologists in the United States, as well as waste disposal specialists associated with AEC operations. Members of the Woods Hole Oceanographic Insti-

tution, the Scripps Institution of Oceanography of the University of California, the Lamont Geophysical Laboratories of Columbia University, and the Chesapeake Bay Institute of Johns Hopkins University, presented prepared discussions. Forty research engineers, oceanographers, and marine scientists took part in the conference. A full record of this conference is in preparation, but it must be edited and approved before it can become available in finished form. Until that time, this present article must serve as a summary.

Results

It appears quite possible and practical to design ocean disposal operations for the specific conditions that will arise. The seas offer many different systems that can be exploited. The major difficulty, in the present preliminary planning stage, is that of framing inquiries so that oceanographers can give definite answers. In some regions it may be possible to explore disposal potentialities empirically. Such practical experiments are desirable for determining whether the mechanics of natural removal of radioactivity by settling materials can be utilized.

Disposal of free wastes by dilution requires further study of mixing patterns in the sea. It cannot be assumed that any large fraction of the oceans' volumes can be used in dilution processes; all experience points to the opposite view. Most liquid wastes will spread and mix rapidly along horizontal strata of comparable densities and viscosities, but vertical mixing into waters of differing characteristics is much slower. This has been proved by mixing experiments with wastes discharged into lakes, harbors, and slow flowing rivers.

The most economical method of disposal would be to discharge high-alkalinity and high-density wastes near the sea surface, with the expectation that these fluids will sink with little mixing to the deeps but this method offers little promise. When discharged at the surface, heavy industrial wastes show a high degree of mixing during passage through the relatively turbulent upper 100 meters of the ocean, where reconcentration by plankton is most likely.

It may be practical to restrict dense, free wastes to sequestered water masses in some of the ocean's deeps. The most promising deep-water masses for waste confinement are those that are surrounded by high rims, shelves, or sills. A number of such well bounded deeps have been described by submarine geologists. Accessibility to these deeps is, of course, an important consideration.

It is necessary to establish the separateness and integrity of these confined masses, and to determine the rates at which the enclosed waters may be exchanged with the surrounding masses. Few of the recognized deep masses have been studied in sufficient detail to permit useful waste disposal design. The discharge into these deeps of a fraction of the projected waste production for the next 50 years may produce thermal-convection mixing and project mixed wastes into the overlying waters. This possibility requires a careful study of thermal stability of the water mass and of thermal loading limits.

Oceanographers do not agree on the rates at which the major ocean masses mix. Some studies indicate deep water ages in the Atlantic to be in the order of 2,000 years—that is, the deep water was displaced from the surface about 2,000 years ago. Other investigations suggest that overturn may be much

more rapid, and that the sea's stability is conditioned by climatic cycles.

Heavy solidified wastes, or encased wastes may be effectively buried in limited areas of the sea floor. Small amounts of low-level laboratory wastes are currently disposed of by casting them in dense concrete cylinders or blocks and dropping them in dump areas. It is commonly believed that such drums and massive packages penetrate or settle into soft, indefinitely deep, bottom ooze, and are forever locked up in the sea floor. This is an erroneous conception, however, because the rates of silt accumulation in most parts of the sea beyond the continental shelf are very low, the ooze layer is thin, and the bottom is well consolidated and unyielding. Experience with wrecks and sunken bodies in harbors and estuaries shows how slowly heavy objects settle in even poorly consolidated sediments. There are, however, a number of well defined, enclosed basins of marine mud where penetration and burial is possible. Some of these lie on the continental shelf, close to land. These deposits exist because they are bounded by firm walls, and there is little chance of density flows or mud slides in such mechanically limited areas. To utilize these areas, precision navigation and spot-coring explorations may be required.

It is very clear that microscopic marine life, the plankton, will concentrate fission products from contaminated waters, and that the assimilated wastes will be further concentrated in the tissues of predatory animals. The level of radioiodine that may be achieved in a major disposal operation at sea may be directly damaging to plankton and small animals. Less is known about the metabolism of strontium and cesium by marine animals, but it has been observed that these isotopes build up in plankton that feed by filtering. The possibilities of seriously contaminating the marine food supply makes it essential that wastes be kept from fertile waters.

It can be shown that mixing wastes of the magnitudes contemplated in a reactor power economy with the volumes of the oceans will appreciably raise the background of the seas. The more important feature of this enrichment is not the total increase in activity, but the high-level concentrations of more toxic fission products that must occur during loading to equilibrium levels. Along with strontium and cesium, the system will contain a variety of daughter elements whose biological properties are unknown, and some of these will have much longer life than the more active parent materials.

This last group of factors points out a requirement that must be met if a significant fraction of reactor-produced wastes is to be discharged into the seas. Acceptable levels for added fission products in the various marine systems must be established. The standards used for drinking water cannot apply here because the concern is not with direct intake of sea water but with a much more complicated series of cycles terminated by concentration in food materials and, possibly, in the chemical and ore resources of the seas.

Land Disposal of Atomic-Reactor Wastes

Arnold B. Joseph

A paper presented on Dec. 15, 1955, sponsored by AWWA, at the Engineers Joint Council's Nuclear Eng. and Science Congress, Cleveland, Ohio, by Arnold B. Joseph, Research Staff Asst., Johns Hopkins Univ., Baltimore, Md.

MANY people have predicted that electric power of the future will be generated, at least in part, by atomic reactors. On this prediction there is general agreement. There is disagreement, however, as to when there will be general and widespread use of reactors for such a purpose. One reason for the disagreement is that no wholly satisfactory and economical method has yet been found to dispose of the radioactive wastes which are created simultaneously with the electric power. The wastes which are of particular concern are those produced in the chemical reprocessing of irradiated nuclear-fuel elements. These are known as high-level wastes.

The AEC is sponsoring a program of research and study for determining safe and economically feasible methods for getting rid of reactor wastes. Research work in contractors' laboratories continually adds to the fundamental knowledge of fission product wastes and what may be done with them. Other groups of scientists are exploring various possibilities for new techniques and methods for permanent disposition of the radioactive wastes on land and in the oceans.

If the industry were limited to the present knowledge of waste handling and disposing methods, the cost of disposal of wastes from power reactors could be restrictive, if not prohibitive, to the development of a reactor program.

Radioactive Wastes

Radioactive wastes arising in the atomic-energy industry vary in quantity, level of activity, toxicity, and physical form. The levels of radioactivity commonly used as the basis for a first broad classification of wastes are: [1] low-level wastes, 0–50 milliroentgens per hour at the emitting surface; and [2] high-level wastes, 2 roentgens per hour or more at the emitting surface.

Although the disposal of low-level wastes is not a matter of great concern, information dealing with such wastes has been included in this article because, except for storage in tanks, all existing waste disposal experience and techniques have involved either low-level wastes only or exceedingly small quantities of high-level wastes. It is not implied that the methods used to dispose of low-level wastes are necessarily suitable for disposal of high-level wastes also, and most of them certainly are not. The background of experience in low level–waste disposal has value only because, except for storage in tanks, there is no experience whatever, with the disposal of high-level wastes.

High-Level Wastes

High-level wastes present difficult disposal problems. To date, no satisfactory or economical method for their disposal has been found. Where produced in quantity, such wastes are presently being stored in tanks. Because of their radioactivity they are extremely dangerous to have around and great caution must be exercised in handling them.

High-level wastes result from the operation of nuclear reactors, and contain the entire spectrum of fission products which are formed when the uranium atoms split or fission. The waste solution itself comes from the chemical process in which unfissioned uranium is separated from the fission products. Besides these fission products, the waste solution contains various salts and acids.

The manner in which the uranium is utilized in the reactor—that is, whether in the solid or liquid form—determines the particular chemical separation process employed, and, therefore, also determines the physical, chemical, and radiochemical characteristics of the particular waste solution. Table 1 presents the ranges of characteristics of typical reactor fuel–processing wastes which can be expected.

TABLE 1

Characteristics of Typical High-Level Reactor Fuel–processing Wastes

Item	Amount
Gross beta activity—*cpm/ml**	1.6×10^{6}–2.2×10^{10}
Alpha activity—*cpm/ml*	6.0×10^{3}–6.0×10^{5}
Radioactivity—*curies/gal*†	1–400
Effective life—*years*	approx. 600
Heat generation—*Btu/hr/gal*	1–3
Volume to be considered—*gal/year*	1–20×10^{6}
Power equivalent—*kwhr/1 g* U^{235}‡	24,000
Fission product wastes—*g/1 g* U^{235}	1
Wastes from processing—*gal/1 g* U^{235} *consumed*	0.5–5.0
Specific gravity	1.1–1.4
Concentration of chemical composition—*moles/liter*§	
Al	0.5–2.5
NO_3	2.0–8.0
H	0.5–3.0
Na	0.1–0.2
F	2.0–3.0
Zr	0.3–0.6
SO_4	0.3–0.6

* Cpm stands for counts per minute.
† Data are for neutralized waste.
‡ At 100 per cent efficiency.
§ Not all the ions listed will be contained in a single waste output.

Low-Level Wastes

Low-level wastes present no difficult disposal problems. Because of their low activity level and relatively short half-life, they can often be dispersed into the environment.

Low-level liquid wastes are rather large in total volume, but low in radioactivity and toxicity. They derive from laundry, laboratory, decontamination operations, and from cooling of reactors.

Low-level solid wastes include such contaminated items as protective clothing, paper towels, blotters, air filters, floor sweepings, animal carcasses, bedding, mechanical and laboratory appurtenances, and other miscellaneous trash associated with daily laboratory and research operations. Although some of these wastes are combustible, incineration is not widely practiced, principally because of the costs involved.

Treatment Methods

Radioactive wastes cannot be "treated" in the conventional sense. They must be disposed of by physical transfer from those areas where they

may be hazardous to areas where they present no serious problems. It is possible to make handling and disposal more convenient by a variety of separating, concentrating, storing, shielding, and packaging methods, but these do not change the rate of fission energy loss. If a disposal method is to be safe and final, the radioactive wastes must either be highly diluted by dispersal or be sequestered for long periods of time.

With low-level liquid wastes, the practice is to hold the wastes on site for decay in storage until they can be safely released into waterways, public sewers, or directly to the ground. High-level wastes are generally stored in underground steel or reinforced-concrete tanks at a cost of $0.37 to $2.00 per gallon (*1*).

To decrease their volume for storage, wastes are sometimes evaporated. High-level wastes containing more than 10^{-5} curies per liter and less than 10 per cent of solids lend themselves to evaporation as a method of concentration. Charles E. Hirsch (*2*), of the Hanford Atomic Energy Plant, Hanford, Wash., has published the following data on evaporation: initial salt solution has specific gravity of 1.07 and a boiling point of 100°C; final salt solution has specific gravity of 1.38 and a boiling point of 113°C; the volume reduction is 75 per cent; the boiling point of disposable sludge is 113°C; the dissolved-solids content is approximately 41.8 per cent; and 1.21 lb of steam is used per 1.0 lb condensate.

Evaporation is costly when compared with regular industrial-waste treatment, and costs of more than 10¢ per gallon of initial liquid waste are not uncommon when all expenses are included. The sludge or concentrate which contains the radioactive materials is stored, or, if low in activity, may be packaged for either land or sea burial.

TABLE 2

Range of Costs of Treatment and Disposal Methods *

Method†	Costs—$	
	High-Level Wastes	Low-Level Wastes
Tank storage	0.37–2.00/gal	
Evaporation	0.14–0.71/gal	
Land burial	not practiced	0.14–2.00/cu ft
Sea burial	not practiced	approx. 10.00/cu ft

* All costs include interest, depreciation, and overhead.
† Land transportation, which is not included here, commonly costs about $0.04 per ton per mile. In transporting high-level wastes under ICC regulations, however, about 95–99 per cent of the tonnage shipped is shielding, which makes this item relatively costly.

Ion exchange, coprecipitation, and crystallization are methods employed in treatment of both low- and high-level wastes in certain instances. Costs vary with volume, level of activity, and the ultimate-disposal method. A process is being developed whereby activities of up to 20 curies of fission products may be concentrated on a milliliter of montmorillonite clay.

Disposal Methods

It is the policy of AEC to allow no return to nature of radioactive wastes

that would create activity levels higher than the established maximum-tolerance limits. It can be readily visualized that low-level wastes can be diluted and dispersed to the environment at or below tolerable levels of activity. High-level wastes, however, have to be considered differently. Half-lives of the fission products range from a few seconds for isotopes like Br^{88} to 20 years for Sr^{90} and to 33 years for Cs^{137}. Assuming no dilution or evaporation, it would take about 600 years for Sr^{90} and Cs^{137} to decay to the respective permissible concentrations listed in Drinking Water Standards (*3*). Because of this long period of activity and the high toxicity involved, any suggested means of disposal must be tested for safety before it can be first practiced.

A large percentage of the high-level liquid and slurry wastes is currently stored in large underground tanks. Tank storage is recognized as a temporary expedient. Until some way is found to dispose of the wastes, more and more tanks must be built. It is hoped that further separation of the useful components, as well as those which are more hazardous and active, may improve the economy and flexibility of tank retention practice, and that the aged low-activity portions of the waste may be separated for disposal in other ways.

The costs of tank retention are high, but an advantage of the method is that the wastes may be kept under control, at least for several years.

A large fraction of the low-level solid radioactive wastes now produced is buried in the soil. Burial areas are carefully selected, taking into account soil stability, permeability, ground water movement, chemical or zeolytic binding, and other conditions.

Radiation levels of these buried solids range from a few milliroentgens to whole roentgens. The more energetic wastes receive greater cover. When suitable soils are available, disposal costs may be greatly reduced by using shallow earth burial. Burial grounds are "dedicated" areas and are fenced, posted, and monitored. This form of disposal is the most economical of those reviewed by the Johns Hopkins University staff in 1953. It is not used nor considered safe, however, for the disposal of large volumes of high-level reactor wastes.

Roughly 95 per cent of the low-level, short-lived, radioactive liquid wastes are currently disposed of in surface waters. Cooling water from reactors is discharged to large rivers. Excessive accumulation of activity in aquatic animals and plants or in silts and slimes must be watched for systematically.

Laboratory wastes containing radioactive isotopes are sometimes treated along with sanitary wastes in a domestic-type sewage treatment plant. Most of the common laboratory isotopes concentrate in the sludges of sewage treatment plants and in the filters and flocs in a water treatment plant. This reduces the amounts which would otherwise find their way into potable waters. Dilution in surface waterways is not recommended for the disposal of high-level wastes.

Laboratories near the sea imbed wastes in concrete or steel drums or other containers for disposal at sea. Sea transportation is usually provided by the Army, the Navy, or the Coast Guard. The possibilities of expanding or modifying current practices in order to handle the greater volumes of higher-level wastes which are expected from an extensive power program remain to be investigated. The expense

of shielding and shipping the material is one of the disadvantages of this method.

Future Problems

The future magnitude of the reactor waste problem can be evaluated in terms of the electric power consumption in the United States. In 1953 the total electric-energy output of the United States was approximately 4.40×10^{11} kwhr (of which about 70 per cent was produced by fuels). The 1953 population was 160×10^6. The 1953 per capita consumption of electric power, then, was

$$\frac{4.40 \times 10^{11}}{160 \times 10^6}$$

or 2.75×10^3 kwhr per capita per year. Assuming that by the year 2000 the United States population will double, that the per capita consumption will triple, and that 10 per cent of the increase in electrical energy produced will be generated by atomic reactors, the nuclear power will be

$$\frac{2(160 \times 10^6) \times 3(2.75 \times 10^3) - (4.40 \times 10^{11})}{10}$$

or 2.2×10^{11} kwhr per year.

One gram of U^{235} will furnish approximately 24,000 kwhr and will produce 1 g of fission products. At a heat-to-power efficiency of 25 per cent, the amount of fission products (in grams) which will be produced in the year 2000 is

$$\frac{2.2 \times 10^{11}}{0.25 \times 24{,}000}$$

or 3.67×10^7 g per year. This is equal to 83,000 lb or 41.5 tons of fission products per year.

Under current processing techniques, these fission products are dissolved or suspended in liquids. Depending on the type of reactor and the chemical-separations process employed, the liquid volumes may be as small as 0.5 gal per gram of U^{235}, or as much as 5 gal per gram of U^{235} for unneutralized waste. The gallons of waste expected would then be between 1.8×10^7 and 18×10^7 gal per year, or roughly 50,000–500,000 gal per day.

One hundred days after removal from the reactor, the radioactivity of these fission products will be approximately 800 curies per gram. Continual addition of fresh wastes to a partially decayed accumulation would build up the total activity to a rather high equilibrium level. Emerson et al (*4*) have calculated such an equilibrium value for a 450-megawatt (electric-power) reactor operating at 1,000-megawatts total power. They assumed that an aqueous, homogeneous reactor is used and that the circulating fuel is processed every day. The total, equilibrium activity of the wastes accumulated at the end of 10 years was calculated to be 625 mega curies (625,000,000 curies).

Future Methods

A wide range of suggestions has been offered for disposing of high-level radioactive wastes. Included among these are such extreme ideas as packing the wastes into rockets and shooting them into space or dumping the wastes in the polar ice caps. Concentration and fixation processes must still be developed and made economical before these methods can be considered.

Other more practical ideas include disposal in the ocean, which has already been touched upon, and disposal in the earth. Even here, however,

there are inherent difficulties with handling and transporting, both safetywise and costwise. A great deal of shielding is required to allow personnel safely to handle and transfer high-level materials. When 95 per cent or more of the shipping weight consists of shielding, it also becomes rather costly to move the wastes about. Although transportation and handling problems remain, they may possibly be circumvented by building the irradiated fuel-processing plant near the disposal site.

The following methods of disposal of high-level wastes have been used or have been suggested as worthy of careful consideration: [1] retention in underground tanks; [2] burial or dispersal in the sea; [3] storage in mines; [4] discharge into deep, isolated, geologic formations; and [5] burial or discharge in geologically and topographically isolated basins. The first two of these methods have already been discussed.

The final choice of a method will depend in part upon the available disposal resources at sites within reasonable distances of nuclear reactor or chemical-processing plants for irradiated fuels. It may therefore be impractical to develop a single disposal technique to the exclusion of all others. Any one of the above methods may have values in terms of availability, capacity, costs, and safety, which may make it the most suitable for a particular situation.

Ground disposal is looked on favorably because it offers a certain degree of control over the wastes—that is, the boundaries of the disposal area can be determined and biochemical effects can be held at a minimum.

It has been suggested that abandoned mines or mine shafts be used for retention or storage of radioactive wastes. Possible objections to this method are, firstly, that mines are frequently not near enough to the source of radioactive-waste production for economical transportation of the wastes and, secondly, that probably only dry mines can be used. Even the dry mines would be practical only for the storage of dry wastes.

Geologic Formations

There are several types of geologic formations which may be suitable for disposal of high-level wastes. These are salt domes, salt strata, deep permeable formations, and structural troughs. Various problems connected with disposal in deep formations were considered at a staff meeting which AEC and its contractors held with geologists on Nov. 15, 1954 in Washington, D.C. The following summaries are based on the discussions from that meeting.

Salt Formation

The salt formations might be utilized in much the same manner in which they are now used for storage of liquefied petroleum gases. Solution cavities, artificially formed by circulating water through wells, would serve as the storage reservoir for waste. Economy is a possible advantage of this method, for it was stated that the cost of storing liquified gases in such cavities is less than the cost of tank storage. Another advantage would be the widespread occurrence of salt formations.

There are a few apparent disadvantages, however. One is that oil is often associated with salt formations, especially with the salt dome. Another is that the salt itself may have commercial value. Stability of the cavity and heat dissipation present problems that would require very careful attention.

Aquifers

In the central United States, there are deep aquifers underlying the Michigan Basin, the Illinois Basin, and other areas which may be suitable for the injection of wastes. These aquifers are several thousand feet deep and are thought to contain water which moves at a rate of no more than 1–5 ft per year. Along the Eastern seaboard, there are permeable beds underlying the coastal plains. The water in these is thought to be flowing seaward at a slow rate. If so, wastes injected into them might be isolated effectively for a very long period of time. In the western United States there are permeable formations underlying much of the great plains and the desert valley areas of the West. Velocities of water movement are thought to be very low. Care would have to be taken to stay away from former oil-producing areas or prospective oil formations. Areas where abandoned or nonproductive wells have been sunk would be dangerous because the location of these wells is not always known and sometimes they are not properly sealed. Abandoned oil-producing formations are quite likely to be reworked in the future by improved processes or for different resources.

Structural Troughs

In the Appalachian Mountains there are places where folding has formed structural troughs. The heavy waste solution might be put in these troughs below the brines, which are moving very slowly, if at all.

In the Great Basin region of the United States the wastes might be introduced, untreated, into an isolated basin. The basin should be hydrologically isolated, remote from people, of little agricultural value, undisturbed by high-velocity winds, and without mineral or oil resources.

A plant for processing irradiated reactor fuels could be located 100 miles or so from the basin and the wastes piped to the disposal area. The practicability of such a plan depends on whether the shipment cost of the used and processed fuels is less than the cost of obtaining the same reduction in health hazard by treatment and disposal of the wastes at less remote sites.

Conclusion

In its search for solutions to the problem of high-level atomic-waste disposal, the AEC, through research contracts with Johns Hopkins University and the National Research Council, is enlisting the aid of leaders in various scientific and industrial fields. Groups of oceanographers, soil scientists, geologists, petroleum engineers, and others are considering the manifold aspects of this problem and are guiding the AEC in establishing research and testing programs leading to safe and economical methods for disposing of high-level wastes.

References

1. Liberman, J. A. & Gorman, A. E. Treatment of Atomic Industry Wastes. *Proc. ASCE*, **80**: Separate No. 422 (1954).
2. Hirsch, Charles E. Treatment of Radioactive Wastes Solutions. AEC Report No. AECD 3291 (1952).
3. *Drinking Water Standards.* Public Health Reports Reprint No. 2697, US Government Printing Office, Washington, D.C. (Mar. 15, 1946); *Jour. AWWA*, **38**:361 (Mar. 1946).
4. Emerson, L. C.; Straub, C. P.; & Struxness, E. G. Preliminary Estimates of Fission Product Quantities Associated With Radioactive Wastes From a Hypothetical Homogeneous Power Reactor. Conference on Sea Disposal of Radioactive Wastes, Woods Hole, Mass. (Aug. 1954).

Removal of Radionuclides From Water by Water Treatment Processes

Roy J. Morton and Conrad P. Straub

A paper presented on Dec. 16, 1955, under the sponsorship of AWWA, at the Engineers Joint Council's Nuclear Eng. and Science Congress, Cleveland, Ohio, by Roy J. Morton, Assoc. Leader, Power Reactor Waste Disposal Project, and Conrad P. Straub, Sr. San. Engr., US Public Health Service, both of Health Physics Div., Oak Ridge National Lab., Oak Ridge, Tenn.

BEFORE a method of treatment for the removal of radioactive materials from water can be selected or provided, the sanitary engineer, consulting engineer, or water works official must know several things. These include: [1] the concentration of radioactive materials in the water to be treated; [2] the composition of radioactive materials in the water; [3] the maximum permissible concentration (MPC) of the individual components comprising the radioactive materials; and [4] the efficiency of the particular process or combination of processes that might be considered for the removal of the various radioelements.

To obtain information on Item 1 (the concentration), the engineer or official must know what radioisotopes are used on the watershed and in what amounts, and the concentrations in which they are discharged. This will aid in the interpretation of counting data from a reasonable number of samples. If only a single radioisotope is found, Item 2 (the composition) presents no problem. Where several radioisotopes are used, however, radiochemical analyses must be made, and these become difficult as the number of radioisotopes in the mixture increases. Information on Item 3 (MPC values) will be found in *National Bureau of Standards Handbooks* No. 52 (*1*). Item 4 (efficiency of treatment process) will be considered later. If radioisotopes for which no information relative to the efficiency of removal afforded by the various treatment processes has been published are encountered, it may be possible for the water works operator to carry out studies to determine the behavior of these radioactive materials in their passage through the plant.

The percentage of removal that must be provided by a particular water treatment process is a function of the initial concentration of the radioactive element and of the MPC value for that radioisotope, as given in the *Handbook* (*1*). Let it be assumed, for example, that the initial concentration of strontium (Sr^{89}) in the raw water amounts to 1.0 microcurie per milliliter ($\mu c/ml$), (or 3×10^{-5} ppm). The removal required to reduce the activity to the MPC value of 7×10^{-8} $\mu c/ml$ (2×10^{-9} ppm) is 99.993 per cent, a very high efficiency of removal. Or, if the efficiency of a particular process and the MPC value are known, the maximum concentration of that component in the water to be treated can be defined. Again, using the example cited above,

if the treatment processes have an overall removal efficiency of 90 per cent, the maximum concentration of Sr^{89} in the untreated water can not be more than 7×10^{-4} μc/ml (2×10^{-8} ppm).

Radioactive Materials

Before speaking specifically of water decontamination and citing experimental results, several important characteristics of radioactive materials should be mentioned.

1. The rate of disintegration (or decay) of radioisotopes cannot be modified by any physical, chemical, or biological processes. In the treatment processes employed, the radioactive materials are transferred from the liquid to the solid phase (chemical precipitates, suspended solids, and sludges). The radioactive materials associated with these solids must still be disposed of in a safe manner.

2. Chemically, the radioactive isotopes react similarly to their stable counterparts. Thus, if a process removes the stable element, as with the precipitation of calcium in softening, radiocalcium will be carried down in the same manner. This statement may be expanded further to include substances such as strontium and barium which are chemically related to calcium—that is, a process designed for the removal of calcium also will remove some of the strontium and barium.

3. The amounts of the radioelements that must be considered are exceedingly small. To illustrate this, Table 1 presents a comparison of the permis-

TABLE 1

Quantitative Comparison of Drinking Water Standards *and Maximum Permissible Concentration of Radioisotopes in Water*

Chemical Constituent	*Drinking Water Standards (2)*		Maximum Permissible Concentration		Radioactive Form
	ppm (mg/l)	*μg/ml*	*μg/ml*	*μc/ml*	
Grounds for rejection					
Lead (Pb)	0.1	1×10^{-1}			
Fluoride (F)	1.5	1.5×10^{0}			
Arsenic (As)	0.05	5×10^{-2}			
Selenium (Se)	0.05	5×10^{-2}			
Chromium (Cr^{+6})	0.05	5×10^{-2}	5.2×10^{-6}	0.5	Cr^{51}
Recommended values					
Copper (Cu)	3.0	3×10^{0}	2.1×10^{-8}	8×10^{-3}	Cu^{64}
Iron and			1.8×10^{-6}	4×10^{-3}	Fe^{55}
Manganese			2.1×10^{-9}	1×10^{-4}	Fe^{59}
(Fe+Mn)	0.3	3×10^{-1}	9.3×10^{-9}	0.2	Mn^{56}
Magnesium (Mg)	125	1.25×10^{2}			
Zinc (Zn)	15	1.5×10^{1}			
Chloride (Cl)	250	2.5×10^{2}	8.9×10^{-2}	2×10^{-3}	Cl^{36}
Sulfate (SO_4)	250	0.83×10^{2} (as sulfur)	1.2×10^{-7}	5×10^{-3}	S^{35}
Phenolic compounds* (C_6H_5OH)	0.001	1.5×10^{-4}	6.7×10^{-4}	3×10^{-3}*	C^{14}

* Assuming that only one of the carbon atoms is radioactive C^{14}.

TABLE 2

Removal of Radioactivity by Chemical Coagulation *

Isotope	Number of Tests	Activity Range *cpm/ml*	pH Range		Percentage Removal	
			Initial	Final	Average	Range
Cs^{137}-Ba^{137} (Cl)	27	19–17,390	7.5–7.8	6.5–7.8	0.5	0–37
Sr^{89} (Cl_2)	54	212–25,950	7.7–7.9	7.5–8.0	3	0–15
Ba^{140}-La^{140} (Cl_2)	81	42–17,150	7.4–7.6	7.2–8.2	59	1–84
	54	42– 5,520	7.4–7.6	6.6–7.9	44	19–59
	54	44– 8,070	7.4–7.6	7.2–7.8	52	27–72
Sc^{46} (Cl_3)	27	163–24,300	7.2–7.8	6.4–8.0	89	62–98
	27	326–20,060	7.6	7.0–7.8	92	62–99+
	27	202–26,100	7.5–7.9	6.9–8.2	91	69–99+
Y^{91} (Cl_3)	54†	188– 4,166	7.5–7.6	6.0–7.6	90	40–99
	81†	367–20,860	8.1	7.8–10.2	92	56–99+
	81†	202–21,450	7.8–8.0	7.6–8.4	86	48–99
	81‡	406–21,500	7.8	7.5–9.1	75	1–98
	81‡	222–21,500	7.1–8.4	7.4–9.5	73	33–98
Zr^{95}-Nb^{95} (oxylate complex)	54	186–27,200	7.4–7.6	6.4–7.9	80	2–99
P^{32} as $PO_4^{\equiv}$	27	228–17,625	7.6	7.4–7.8	96	68–99+
Cr^{51} (Cl_3)	54	5– 758	6.7–7.3	5.3–7.8	6	0–60
Mo^{99} (O_3)	54	84–10,085	7.6	7.0–8.2	10	0–60
W^{185} (tungstate)	54	233–28,290	7.5–7.9	6.6–8.4	46	1–96
	81	198–22,490	8.0–8.1	7.5–8.4	36	4–91
Re^{186} (metal)	54	95–15,230	7.6	7.2–8.0	6	0–29
I^{131} (iodide)	27	239–25,060	7.6	7.2–7.8	20	0–44
Ru^{103} (Cl_3)	27	196–24,960	7.3–7.6	6.9–8.2	77	43–96
Pr^{142} (as Pr_2O_3)	27	102–12,050	7.3	7.4–8.0	96	83–99+
Ce^{144}-Pr^{144} (Cl_3)	27	244–30,510	7.4–7.6	7.2–8.4	91	28–99+
Pm^{147} (Cl_3)	27	136–19,040	7.4–7.6	7.0–8.2	87	4–99+
Sm^{153} (as Sm_2O_3)	54	148–20,870	7.4–7.6	5.8–8.0	91	44–99+
F. P. mixture	27	216–32,320	7.4–7.6	7.4–8.2	73	46–86

* Evaluations were made of ferrous sulfate, ferric chloride and aluminum sulfate in samples of 1, 2, and 6 grains per gallon (gpg) (17, 34, and 103 ppm, respectively). A 1-gpg sample means a sample containing 1 gpg of the ferrous sulfate, ferric chloride, or aluminum sulfate, 0.4 gpg (86.8 ppm) of activated sodium silicate, and 1 gpg of $Ca(OH)_2$ or Na_2CO_3. The 2-gpg and 6-gpg samples are multiples of the basic 1-gpg sample.

† $Ca(OH)_2$ was used as the alkaline agent.

‡ Na_2CO_3 was used as the alkaline agent.

sible levels of specific elements in the US Public Health Service *Drinking Water Standards* (*2*) with the concentrations indicated for radioisotopes of these elements. It will be seen that the permissible levels from the standpoint of radioactivity are far lower than the concentrations permitted on the basis of the *Drinking Water Standards*.

4. Because the radioactive elements are present in such low concentrations, the usual qualitative and quantitative procedures cannot be used in the identification of the elements. Because these materials are radioactive, however, this characteristic may be utilized to detect, measure, and identify them.

Conventional Processes

Conventional water treatment processes include coagulation, settling, filtration, and disinfection. In addition, auxiliary treatment such as aeration, softening, or iron and manganese re-

moval may be included. In the course of the experimental studies carried out at Oak Ridge National Laboratory, Oak Ridge, Tenn., by the Public Health Service, the Engineer Research and Development Laboratory (Fort Belvoir), the Tennessee Valley Authority, and the Oak Ridge Laboratory, the conventional processes that appeared to show promise for removal of radioactive contaminants were evaluated. Nonconventional processes, including clay adsorption, phosphate coagulation, adsorption on metal powders, electrodialysis with permselective ion-exchange membranes, and evaporation, were also investigated.

iron salts are the most common coagulants.

Coagulation, followed by settling, has been studied rather extensively at the Oak Ridge National Laboratory, where standardized jar test procedures were used and aluminum sulfate, ferrous sulfate, and ferric chloride were evaluated. To conserve time and effort, statistical procedures were employed in planning and carrying out the experiments. A reexamination and recalculation of an earlier 3^4 factorial experiment, in which the simultaneous effects of turbidity, coagulant dose, pH, and activity in counts per minutes (cpm) were determined, indi-

TABLE 3

Removal of I^{131} by Auxiliary Processes

Dosage				Final Characteristics			Percentage Removal	
Turbidity *ppm*	Alum *ppm*	NaOH *ppm*	Auxiliary Chemical *ppm*	pH	Alkalinity *ppm*	Turbidity *ppm*	Coagulation and Settling	Coagulation, Settling, and Centrifuging
103	25.7	38.9	5–15*	5.8–7.1	17–68	0–15	64–72	74–78
103	25.7	38.9	3.5†	7.1	65	0	38	56
17.3–274	25.7	38.9	0.12–3.8‡	5.8–7.5	19–74	1–40	42–74	48–76
	123.5		0.013–0.13‡	6.0–6.9			55–90	
	247		0.13–1.1‡	6.3			90–92	
	100.64§		0.13	6.3			95.5	

* Auxiliary chemical was activated carbon.
† Auxiliary chemical was copper sulfate.
‡ Auxiliary chemical was silver nitrate.
§ 20 ppm as Fe or 100.64 ppm as $Fe_2(SO_4)_3 \cdot 9\ H_2O$.

Coagulation

Coagulation involves the formation of chemical flocs that adsorb, entrap, or otherwise bring together suspended matter, particularly suspended matter that is colloidal. The addition of coagulating chemicals will result also in the precipitation of some of the soluble constituents in the waste as metal hydroxides, generally as hydroxides of aluminum or iron, because alum and

cated that a one-third replication of the 3^4 experiment would provide equally reliable interpretation of the factor interactions (*3*).* Through

* A 3^4 factorial experiment means that four independent variables were investigated at three separate levels. In the original factorial experiment the simultaneous effects of turbidity, coagulant dosage, pH, and initial radioactivity dosage were evaluated at three levels. In the second factorial experiment, evaluations were made of different coagulants (aluminum sulfate, ferric chloride, and ferrous sulfate), initial radioactivity dosage (at three levels), tap water (variation over a 3-day test period), and coagulant dosages of 1, 2, and 6 grains per gallon (gpg) (17, 34, and 103 ppm, respectively). The one-third replication means that a

TABLE 4

Coagulation and Settling Results—Jar Test Studies

Isotope	Clay Added* *ppm*	Coagulant Added† *ppm*	Final pH	Percentage Removal
Cs^{137}-Ba^{137}	0	1		0– 6
	100	1		35–65
Sr^{89}	0	1.5‡	6.7– 7.8	0– 6
	100	0.5–6	6.7–10.7	0–51
Cd^{115}	0	1		40–60
	100	1–5		60–95
Ba^{140}-La^{140}	100	1–6	7.5– 8.2	28–84
Sc^{46}	100	1–6	6.5– 8.2	66–98
Y^{91}	0	1.5‡	6.8– 7.1	83–93
	100	1–6	7.0–10.2	34–99
Zr^{95}-Nb^{95}	0	1–5		70–98
	100	1		95–99
P^{32}	100	0.5–1.5‡	6.8– 8.8	97–99
Cr^{51}	100	1–6	7.6– 8.8	73–98
W^{185}	100	1–6	7.5– 8.4	5–91
I^{131}	100	0.5–2‡	6.9– 9.0	0–10
Ce^{144}	0	1–1.5‡	7.2– 7.8	81–94
	100	0.5–2.5‡	7.0– 7.8	85–96
FPM-1§	100	1–3‡	7.2– 8.8	61–84
FPM-2‖	0	1–5	4.3–10.2	9–71
	100	1–5	4.3–10.2	12–73
FPM-3#	0	10	9.9–10.0	46

* Local clay was added.
† Coagulant includes alum, ferrous sulfate or ferric chloride, lime, soda ash or sodium hydroxide, and sodium silicate. Where used, sodium silicate equaled 40 per cent primary coagulant dose.
‡ No sodium silicate added.
§ FPM-1 was an iodine dissolver solution.
‖ FPM-2 was a synthetic mixture containing fission products in the same concentrations assumed to be present 30 days after an underwater bomb blast.
FPM-3 was a 3-year old fission product mixture.

the use of this technique, it was possible to reduce the number of jar tests from 243 to 54 for each series, or to two-ninths of the original effort. The results of these studies are summarized in Table 2.

Phosphorus (P^{32}) has been removed from contaminated waters (*4, 5*), but considerable care had to be given to the coagulation steps (*5*). Removals in excess of 98 per cent have been reported. Iodine (I^{131}), which has found most extensive use in medical therapy and research, cannot be removed by coagulation with alum or iron because the element is in the form of an anion. The addition of small amounts of activated carbon (*4*), copper sulfate (*4*), or silver nitrate (*4, 6*), however, has increased removals of this anion from water to about 96 per cent. Some of these results are indicated in Table 3.

Coagulation will be helpful also in the removal of radioactive material attached to or adsorbed on the natural turbidity found in many surface waters. Since coagulation will remove much of the turbidity, the activity attached to it will also be removed. The effect of added turbidity on the removal of cer-

third of the total experiment was carried out on each succeeding day of the test until the experiment was completed—that is, for three days. In the original experiment, the individual error was calculated from the variation found in running triplicated samples, while, in the second experiment, the error was calculated from the variation between duplicated samples.

tain radioisotopes is illustrated by the data in Table 4.

As might be expected, pH exerts an appreciable effect on removal. Table 5 shows this effect on the removal of mixed fission products by filtration, and Table 6 indicates the effect of pH on the removal of ruthenium by coagulation. Increased chemical dosages do not necessarily result in greatly increased removals of activity. In coagulation of a fission products mixture with ferric chloride, for example, a twenty-old increase in the coagulant dose (from 10 to 200 ppm) resulted in less than 14 per cent increase in removal of radioactive materials (from 77.9 to 88.6 per cent removal).

TABLE 5

Effect of Increased pH on Removal of Mixed Fission Products by Filtration

pH	Percentage Removal
2.5	14.6
6.2	63.1
8.6	80.7
10.5	85.1
12.2	88.6

Sand Filtration

Except for removal by simple straining or sorption by biological life contained in the *schmutzdecke*, or slimy layer covering filters, sand filters have not been effective for the removal of radioactive materials (*7–9*). Their major function is to remove the radioactivity previously incorporated in floc particles during coagulation. Some typical results from single-pass, downflow filtration through sand columns are shown in Table 7.

Softening

Softening with lime and soda ash has been studied and, under proper conditions, effective removals of strontium, barium, cadmium, yttrium, scandium, and zirconium-niobium have been obtained (*9–12*). Removal efficiencies of 95–99 per cent or higher are possible. For most satisfactory removal of strontium, Hoyt (*10*) found that excesses of both lime and soda ash were required. His results are summarized in Table 8. The strontium present was reported to be removed by coprecipitation with the calcium carbonate by the mechanism of mixed crystal formation (*10, 12*). Data on the removal of stable strontium by municipal water treatment processes, including softening, have been reported (*13*) and are given in Table 9.

TABLE 6

Effect of pH on Removal of Ruthenium

Coagulant Dosages*	Percentage Removal	
	pH Range of 2.5–4.4	pH Range of 7.5–8.4
$FeSO_4$		
1 gpg	10	75
2 gpg	13	84
6 gpg	30	98
$FeCl_3$		
1 gpg	4	92
2 gpg	5	90
6 gpg	14	94
Alum		
1 gpg	3	74
2 gpg	4	91
6 gpg	9	92

* 1 gpg is equal to 17 ppm.

As has been indicated above, lime-soda softening is fairly effective in removing specific radioelements if relatively high chemical dosages are employed. From the standpoint of emergency water treatment, this process is not generally applicable because water works serving less than 15 per cent of

this country's population are presently equipped for softening water. Also, exceedingly high dosages would be required to effect substantial reduction of mixed fission products. Other water treatment processes, with the exception of ion exchange, are relatively ineffective in removing strontium, whereas lime-soda softening, under optimum conditions, can effect removal in excess of 99 per cent (*10*).

Ion Exchange

Another method of softening used in municipal water treatment practice is ion exchange. Removal of radioactive materials by this process is technically possible (*9, 11, 14, 15*), and, for most effective removals, mixed-bed ion-exchange resins in series are recommended. Some results with various types of exchange materials are shown in Table 10, and are compared with removals obtained with greensands (*9*), which are used in municipal softening installations. In these studies, the cation-exchange materials evaluated included IR-120 * (H^+ and Na^+ cycles) and a natural greensand (Na^+ cycle); the anion exchangers included Dowex-1 † (OH^- and Cl^- cycles); and the mixed beds included an IR-120 (H^+) and Dowex-1 (OH^-) bed and an IR-120 (Na^+) and Dowex-1 (Cl^-) bed. In general, the particular regeneration cycle—that is, whether H^+- or Na^+-regenerated cation-exchange resin or OH^-- or Cl^--regenerated anion-exchange resin—did not appreciably influence the results. The effluent pH may be significant in water treatment practice. The range in effluent pH for the various materials studied was as follows: IR-120 (H^+), 2.8–3.6; IR-120 (Na^+), 3.4–4.3; Dowex-1 (OH^-), 10.7–11.2; Dowex-1 (Cl^-), 7.2–8.7; and greensand, 7.1–8.0. The removal efficiencies with greensand do not appear to be significantly different from the sodium cycle cation-exchange resin results, but the total capacities of the resins undoubtedly differ greatly.

It should be noted that strontium, cesium, cadmium, and, to a lesser extent, barium-lanthanum are present in solution as cations, whereas tungsten

TABLE 7

Laboratory Sand Filtration Results

Isotope	Initial Activity *cpm/ml*	Volume Passed *ml*	pH of Effluent	Percentage Removal	
				Range	Average
Cs^{137}-Ba^{137}	800	500	8.3	10–70	50
Sr^{89}	2,700	750	8.3	1–13	4
Cd^{115}	1,200	500	8.1	60–99	95
Ba^{140}-La^{140}	1,300	750	7.6	39–99	74
Sc^{46}	1,500	750	8.3	94–99	96
Y^{91}	5,700	750	7.0	84–89	87
Zr^{95}-Nb^{95}	3,400	500	7.8	91–96	93
W^{185}	2,200	750	7.1	3–18	8

* IR-120, a cation-exchange resin, is a product of Rohm and Haas Co., Philadelphia, Pa.

† Dowex, a strong-base anion-exchange resin, is a product of Dow Chemical Co., Midland, Mich.

TABLE 8

Results of Lime–Soda Ash Treatment for Removal of Strontium

Treatment	Percentage Removal
Stoichiometric amounts	75.0
20-ppm excess lime–soda ash	77.0
50-ppm excess lime–soda ash	80.1
100-ppm excess lime–soda ash	85.3
150-ppm excess lime–soda ash	97.3
200-ppm excess lime–soda ash	99.4
300-ppm excess lime–soda ash	99.7

is present as an anion. Yttrium, scandium, and zirconium-niobium are apparently in colloidal form and, as such, are partly removed on both cation- and anion-exchange resins.

A more extended study of ion exchange was made by Friend (*14*), who investigated this procedure for the removal of I^{131}, Sr^{89}, and mixtures of the two radioisotopes. He reported a decontamination factor (influent activity divided by effluent activity) in excess of 10^2 (more than 99 per cent removal) for carrier-free I^{131} through the use of IRA-400 * resin (OH^- cycle) or a combination of IR-120 (Na^+ or H^+ cycles) and IRA-400 (OH^- cycle); a decontamination factor in excess of 10^3 (more than 99.9 per cent removal) for carrier-free Sr^{89} through the use of IR-120 (H^+ cycle) or a combination of IR-120 (H^+ or Na^+ cycles) and IRA-400 (OH^- cycle); and a decontamination factor in excess of 10^3 (more than 99.9 per cent removal) for the carrier-free mixture of Sr^{89} and I^{131} through the use of IR-120 (H^+ or Na^+ cycles) and IRA-400 (OH^- cycle).

Further studies on the use of mixed cation- and anion-exchange resin slurries * for the removal of a variety of radioisotopes from water solution have been made by Lacy and are summarized in Table 11.

Although the ion-exchange process offers one of the most efficient methods for removing radioactive contaminants from water, the cost of the resins may preclude widespread usage unless suitable regeneration techniques are developed.

TABLE 9

Strontium Removal by Chemical Treatment

Type of Treatment	Percentage Removal		Number of Cities
	Avg.	Range	
Alum or ferrous sulfate	12	10–31	7
Alum or ferrous sulfate, plus lime	37	10–75	11
Alum or ferrous sulfate, plus lime and soda ash	54	10–85	3
Alum or ferrous sulfate, plus lime and phosphate	42	10–70	5
Softening only (phosphate, ion exchanger)	73	69–76	2
None (except chlorine, fluoride, carbon, or ammonia)	10		8

Nonconventional Processes

Several other methods have been studied for the removal of radioactive constituents from water. These are of particular interest as possible methods for emergency treatment or other nonconventonal applications. The most promising of these, phosphate coagulation (*16, 17*), has effected removals

* IRA-400, a strong-base anion-exchange resin, is a product of Rohm and Haas Co., Philadelphia, Pa.

* Amberlite MB-3, a product of Rohm and Haas Co., Philadelphia, Pa. was used.

TABLE 10

Percentage of Removal Resulting From Individual Isotopes With Ion Exchange Materials

Isotope	Ion Exchange Material			
	Cation Exchange	Anion Exchange	Mixed Bed	Greensand
W^{185}	12–16	97.2–99.2	98.9	9
Y^{91}	86–93.1	94.2–98.5	97.6 –98.7	75
Sc^{46}	95.7–97.2	98.8–99.0	98.5 –98.7	96.4
Sr^{89}	99.1–99.8	5–7	99.95–99.97	99.8
Ba^{140}-La^{140}	98.3–99.0	36–42	99.5 –99.6	96.3
Cs^{137}	99.8	9	99.8	
Cd^{115}	98.5	0	99.2	
Zr^{95}-Nb^{95}	58–75	96.4–99.9	90.9 –99.4	

of up to 99.9 per cent, as shown by the data included in Table 12. Relatively high removals of strontium are also possible with this method, but these can be secured only under carefully controlled conditions of pH and of the calcium hydroxide–trisodium phosphate ratio, as illustrated in Fig. 1.

Studies utilizing an electrodialytic cell with permselective ion-exchange membranes (*18*) indicated the necessity of removing all colloidal radioelements prior to concentration of the soluble radioisotopes in the cell. Passage of various radiocolloids through a molecular filter membrane * has shown that the larger colloids, such as Zr^{95}–Nb^{95}, were removed completely, whereas others, such as Ru^{103} and Ce^{144}, were removed only in part. Therefore, if the dialytic cell is to be effective for the removal of the soluble radioactive materials, the radiocolloids should be removed beforehand.

Other methods suggested for the removal of radioactive materials include

* Filters used were products of the Millipore Filter Corp., Watertown, Mass.

TABLE 11

Removal of Radioactive Contaminants From Water by Combined Anion-Cation Resin *

Contaminant	Initial pH	Initial Activity *cpm/ml*	Percentage Removal†			
			A	*B*	*C*	*D*
P^{32}	8.2	5,560	47.4	74.5	96.2	99.8
Cd^{115}	8.0	7,880	37.9	45.6	91.1	99.99
Cs^{137}-Ba^{137}	8.2	8,200	15.1	14.6	69.1	99.99
Zr^{95}-Nb^{95}	8.1	6,700	98.3	98.4	99.2	99.4
I^{131}	7.5	3,200	84.5	93.5	95.6	98.1
$Ce^{141, 144}$-$Pr^{141, 144}$	7.9	4,150	98.7	99.2	99.8	99.98
Ba^{140}-La^{140}	7.6	3,490	85.1	94.5	98.8	99.9
FPM-4‡	8.3	13,600	82.7	90.5	97.3	99.2
FPM-5§	2.7	3,400	38.4			

* Data were obtained from jar test studies, using filtered samples and a stirring time of 90 min.
† Columns *A–D* give data for resin contents of 450 ppm, 900 ppm, 1,800 ppm, and 2,700 ppm, respectively.
‡ FPM-4 was a 30-day old iodine dissolver solution.
§ FPM-5 was a mixed-fission product waste containing mainly Cs^{137}-Ba^{137} and Ru^{106}-Rh^{106}.

TABLE 12

Removal of Radioisotopes by Phosphate Coagulation

Isotope	Coagulant	Coagulant Dose *mg/l*	Percentage Removal
Ce^{144}	KH_2PO_4	200	99.8
	Na_3PO_4	120	99.9
Sr^{89}	KH_2PO_4	100	81.3
	Na_3PO_4	240	97.8
Y^{91}	KH_2PO_4	100	99.9
Sb^{124}	KH_2PO_4	100	66.1
	Na_3PO_4	120	67.4
Zn^{65}	KH_2PO_4	50	99.6
W^{185}	KH_2PO_4	200	10.7
Zr^{95}	KH_2PO_4	100	99.5
Nb^{95}	KH_2PO_4	100	99.2

the use of metal powders and added clay materials. Laboratory jar test studies, using various metal dusts to remove specific radioactive contaminants, were carried out by Lacy (*19*), and data are shown in Table 13. In general, the best results were obtained with the iron dust, with removals exceeding 90 per cent, except with fission products mixture iodine, and cesium. From these results Lacy concluded that adsorption was the primary mechanism involved in the removal of the radiocontaminants. Other mechanisms such as metallic displacement may, however, be responsible for some of the removals reported.

Considerable work has been reported (*4, 20–22*) on the use of clay materials for the removal of specific radioisotopes from water. Some results are indicated in Table 14. Although this method is feasible, it involves working with large volumes of clay, both initially and as a contaminated mass of material. Furthermore, if combined with chemical coagulation, still larger volumes of radioactively contaminated sludge must be handled for disposal. The adsorption of radiosiotopes on clays has its greatest potential value where the geologic and hydrologic conditions are such that the ground itself will retain radioactive materials and re-

TABLE 13

Removal of Radioactive Contaminants by Metallic Dusts *

Contaminant	Stock Solution pH	Initial Activity *cpm/ml*	Percentage Removal			
			Fe†	Zn	Cu	Al
Ru^{106}-Rh^{106}	8.0–8.2	1,975– 3,950	99.6	98.4	93.7	92.8
Y^{91}	7.9–8.0	1,610– 3,230	98.0	98.0		
Zr^{95}-Nb^{95}	7.2–8.3	1,210– 4,470	99.1	97.9	99.1	99.8
P^{32}	7.8–8.4	128–12,000	99.8	98.1		84.2
I^{131}	6.5–8.2	4,288– 6,689	37.2	45.7	42.2	23.2
$Ce^{141, 144}$-Pr^{144}	7.9–8.1	3,915– 4,491	99.9	99.9	99.5	99.8
Ba^{140}-La^{140}	7.9–8.2	4,644–10,205	94.8	74.5	65.7	73.8
Co^{60}	8.0–8.2	1,571– 4,792	92.2‡§		47.8	30.2‡
FPM-6‖	7.2–8.0	4,730–10,375	85.8	76.6	92.1	89.4
FPM-5#	2.0–7.2	2,890– 4,220	55.5	39.6	49.3	8.2
Cs^{137}-Ba^{137}	8.0	13,085	8.6			

* Tests used filtered sample, 90-min contact, and 1,000 ppm metal dust.
† Fe samples were centrifuged before counting.
‡ 500 ppm metal dust was used.
§ 60-min contact was used.
‖ FPM-6 was a 20-day old iodine dissolver solution.
FPM-5 was a mixed-fission product waste containing mainly Cs^{137}-Ba^{137} and Ru^{106}-Rh^{106}.

duce the danger that underground water supplies will be contaminated.

Evaporation

Evaporation, although it is not a municipal water treatment method, is included in this discussion because it is the most effective process presently available for concentrating the radioactive materials. Under proper conditions, a condensate very low in activity can be produced. High decontamination factors are possible, but the cost is relatively great. Under emergency conditions, however, evaporation should prove very satisfactory.

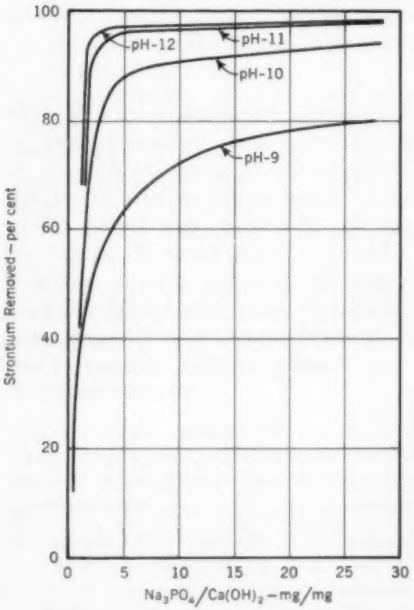

Fig. 1. Effect of pH and Calcium Hydroxide–Trisodium Phosphate Ratio on Removal of Strontium

Phosphate coagulation has been very successful for removal of radioactive constituents from water, but, as shown here, pH and the calcium hydroxide–trisodium phosphate ratio must be carefully controlled.

TABLE 14

*Effect of Added Clay on Removal of Radioisotopes**

Radioisotope	Percentage Removal		
	100 ppm Clay	750 ppm Clay	5,000 ppm Clay
Ba^{140}-La^{140}	41	58	85
Cd^{115}	3	30	64
Ce^{144}	70–80	86	
Cs^{137}	38	87	98.0
Sc^{46}	53	91.7	96.9
Sr^{89}	2–12	14–22	49–52
W^{185}	0	4	49
Y^{91}	22–45	56–70	93.6
Zr^{95}-Nb^{95}	93.5	99.0	98.0

* Local clay was added to produce turbidity.

Removal of Mixed Fission Products

The previous discussion has centered on the removal of specific radioisotopes from aqueous solutions. With a fission products mixture, or any mixture of radioisotopes, however, the efficiency of removal is a function of the individual radioisotopes comprising the mixture. Removals in laboratory experiments to date have been in the order of 70–80 per cent with alum or iron coagulation (*4*). A series of studies on actual radioactive process waste waters at the Oak Ridge National Laboratory disclosed that removals up to 90 per cent could be obtained with excess lime–soda ash softening and phosphate coagulation, when clay was added for the removal of the cesium in the waste (*23*). Results of laboratory tests with this waste material are summarized in Table 15. Other experimental data with fission products mixtures are given in Table 16.

TABLE 15

Laboratory Studies on Removal of Radioactivity From Process Wastes

Type of Sample	Number of Observations	Treatment	Percentage Removal	
			Avg	Range
Grab*	5	Alum coagulation	28	23–32
Grab*	5	Ferrous sulfate coagulation	32	15–44
Grab*	5	Phosphate coagulation	73	66–82
Grab*	4	Excess lime-soda ash	70	61–78
Grab*	1	Variable clay (100–1,000 ppm)		39–52
Grab	20	Phosphate coagulation	70	43–83
8-hr composite	6	Phosphate coagulation	70	46–78
8-hr composite	6	Excess lime-soda ash	37	19–48
8-hr composite	7	Serial treatment—clay and phosphate coagulation	90	82–93
8-hr composite	6	Serial treatment—clay and excess lime-soda ash softening	84	82–88

* Preliminary tests.

Summary and Conclusions

Unless related to the initial concentration of the radioactive materials present, the percentage removal values cited during this discusison have little significance. It is only when the efficiency of removal is considered in terms of the initial concentration and the maximum permissible concentration values that safety of the treated water for human consumption can be definitely determined. Generally speaking, water treatment processes will not effectively reduce the activity in the water to acceptable safe limits except where the initial levels of activity are very low, certainly several orders of magnitude below the 1.0 μc/ml level.

In order to minimize the contamination of water supplies, radioactive ma-

TABLE 16

Removal of Mixed Fission Products Isotopes

Mixture*	Treatment Process	Percentage Removal
FPM-1	Coagulation and settling plus clay	61–84
FPM-2	Coagulation and settling	9–71
	Coagulation and settling plus clay	12–73
	Coagulation and settling plus clay	46
	Coagulation and settling plus filtration plus clay	70–73
FPM-3	Coagulation and settling	46
FPM-4	Coagulation and settling	89
	Mixed cation-anion exchange slurry	83–99
FPM-5	Coagulation and settling	51–59
	Mixed cation-anion exchange slurry	38
	Metallic-dust slurry	8–56
FPM-6	Metallic-dust slurry	77–92

* FPM-1 was an iodine dissolver solution; FPM-2 was a synthetic mixture; FPM-3 was a 3-year old fission products mixture; FPM-4 was a 30-day old iodine dissolver solution; FPM-5 was a mixed-fission product waste containing Cs^{137}-Ba^{137} and Ru^{106}-Rh^{106}; FPM-6 was a 20-day old iodine dissolver solution.

terials should be retained as close to their source of production as possible. The practice at present is predominantly tank storage. As has been pointed out, the transfer of activity from the liquid to the solid phase by water treatment processes does not eliminate the problem, since suitable storage or disposal facilities must be provided for radioactive sludges, filter wash water, and other contaminated by-products.

To protect large population centers dependent on surface waters which may become contaminated by radioactive materials, plans should be made for auxiliary water sources from possible noncontaminated supplies. For this purpose, existing ground water supplies may be used, other interconnected water supplies may be piped in, or special provisions may be made for bringing water from the outside. These precautionary measures, however, will be effective only in those areas where the contamination from radioactive materials is low enough so that there will be no hazard from external radiation.

Acknowledgment

The results presented herein are from the composite effort of many individuals representing several agencies, and the writers are merely reporting their findings. Appreciation and thanks are accorded to these individuals and agencies for carrying out the various studies and for use of their data.

References

1. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. *National Bureau of Standards Handbooks,* No. 52 (Mar. 20, 1953).
2. *Drinking Water Standards.* Public Health Reports Reprint No. 2697, US Government Printing Office, Washington, D.C. (Mar. 15, 1946); *Jour. AWWA,* **38**:361 (Mar. 1946).
3. Health Physics Div. Semiannual Progress Report for Period Ending Jul. 1, 1953. Rept. ORNL-1596. Oak Ridge National Lab., Oak Ridge, Tenn. (Sep. 30, 1953).
4. Straub, Conrad P.; Morton, Roy J.; & Placak, Oliver R. Studies on the Removal of Radioactive Contaminants From Water. *Jour. AWWA,* **43**:773 (Oct. 1951).
5. Eliassen, Rolf, et al. Studies on Radioisotope Removal by Water Treatment Processes. *Jour. AWWA,* **43**: 615 (Aug. 1951).
6. Eden, G. E.; Downing, A. L.; & Wheatland, A. B. Observations on the Removal of Radioisotopes During Purification of Domestic Water Supplies: I—Radioidine. *J. Inst. Water Engrs.,* **6**:511 (Nov. 1952).
7. Eden, G. E.; Elkins, G. H. J.; & Truesdale, G. A. Removal of Radioactive Substances From Water by Biological Treatment Processes. *Atomics,* **5**:133 (May 1954).
8. Gemmell, Lee. Efficiency of Filter Beds for Treating Radioactive Waste. *Nucleonics,* **10**:40 (Oct. 1952).
9. Straub, Conrad P., et al. Unpublished data. Oak Ridge National Lab., Oak Ridge, Tenn.
10. Hoyt, W. A. The Effects of the Lime-Soda Water Softening Process on the Removal of Radioactive Strontium 90-Yttrium 90. Master's thesis, North Carolina State College, Raleigh, N.C.
11. Downing, A. L.; Wheatland, A. B.; & Eden, G. E. Observations on the Removal of Radioisotopes During the Treatment of Domestic Water Supplies: II—Radiostrontium. *J. Inst. Water Engrs.,* **7**:555 (Nov. 1953).
12. McCauley, Robert F. & Eliassen, Rolf. Radiostrontium Removal by Lime-Soda Softening. *Jour. AWWA,* **47**:494 (May 1955).
13. Alexander, George V.; Nusbaum, Ralph E.; & MacDonald, Norman S. Strontium and Calcium in Municipal Water Supplies. *Jour. AWWA,* **46**:643 (Jul. 1954).
14. Friend, A. G. Report on the Investigation of the Removal of Iodine (I^{131}) and Strontium (Sr^{89}) From Water by

Ion-Exchange Resins. Master's thesis, Virginia Polytechnic Inst., Blacksburg, Va. (Jun. 8, 1952).

15. AYRES, JOHN A. Treatment of Radioactive Waste by Ion Exchange. *Ind. Eng. Chem.*, **43**:1526 (Jul. 1951).
16. LAUDERDALE, ROBERT A., JR. Studies on the Removal of Radioisotopes From Liquid Wastes by Coagulation. Rept. ORNL-932. Oak Ridge National Lab., Oak Ridge, Tenn. (Jan. 23, 1951); *Ind. Eng. Chem.*, **43**:1538 (Jul. 1951).
17. NESBITT, JOHN B., ET AL. The Removal of Radioactive Strontium From Water by Phosphate Coagulation. Rept. NYO-4435. Massachusetts Inst. of Tech., Cambridge, Mass. (Feb. 15, 1951).
18. SEAL, M. S. & PECSOK, D. A. Preliminary Laboratory Evaluation of an Electrolytic Method for the Treatment of Radioactive Waters. Unpublished report. Oak Ridge National Lab., Oak Ridge, Tenn. (Jul. 1954).
19. LACY, WILLIAM J. Removal of Radioactive Material From Water by Slurrying With Powdered Metal. *Jour. AWWA*, **44**:824 (Sep. 1952).
20. BROCKETT, T. W., JR. & PLACAK, O. R. Removal of Radioisotopes From Waste Solutions by Soils—Soil Studies With Conasauga Shale. *Proc. 8th Ind. Waste Conf.* Extension Series No. 83. Purdue Univ., Lafayette, Ind. (Jan. 1954). p. 393.
21. STRAUB, CONRAD P. & KRIEGER, HERMAN L. Removal of Radioisotopes From Waste Solutions—Soil Suspension Studies. *Proc. 8th Ind. Waste Conf.* Extension Series No. 83. Purdue Univ., Lafayette, Ind. (Jan. 1954). p. 415.
22. LACY, WILLIAM J. Decontamination of Radioactively Contaminated Water by Slurrying With Clay. *Ind. Eng. Chem.*, **46**:1061 (May 1954).
23. KRIEGER, HERMAN L. & STRAUB, CONRAD P. Unpublished data. Oak Ridge National Lab., Oak Ridge, Tenn. (Feb. 1954).

Measuring Ground Water Movement With Radioactive and Chemical Tracers

Warren J. Kaufman and Gerald T. Orlob

A paper presented on Oct. 27, 1955, at the California Section Meeting, Sacramento, Calif., by Warren J. Kaufman, Asst. Prof. of San. Eng., and Gerald T. Orlob, Asst. Prof. of Civ. Eng., both of the University of California, Berkeley, Calif.

THE direct measurement of ground water movement is often of particular interest to those water supply engineers charged with the responsibility of protecting or developing a ground water basin. In many western states the underflow discharge of intermittent streams often represents a major portion of the water available from a watershed. The early tracer applications of Slichter (*1, 2*) to ground water velocity measurements, for instance, were largely concerned with such underflow studies in Southern California. Considerable interest has also developed in tracer methods as means of determining the origin of seepage water and the location of leaks in water transportation and storage systems. Increased application of injection methods for disposing of brines and chemical wastes has created a further need for improved techniques of anticipating the direction and rate of travel of chemical pollutants. Other instances where a greater understanding of flow through porous media would be valuable include the intrusion of saline waters into coastal freshwater aquifers and the evaluation of proposed methods of subsurface disposal of radioactive wastes. The investigation described here is intended to ascertain the adequacy of several organic, inorganic, and radioactive materials in performing the function of tracing the movement of water through porous media. Of primary concern is the delineation of factors which cause adsorption of the tracer by the medium, thus producing a distorted picture of the underground flow pattern.

Characteristics of Ideal Tracer

The properties of the ideal ground water tracer have been described by numerous authors. Carpenter, Morgan, and Parsons (*3*), for example, have set forth the following requirements for a satisfactory tracer to be used in measuring the movement of flood waters in the secondary recovery operations of the petroleum industry:

1. A satisfactory tracer should be susceptible to quantitative determination in very low concentration.
2. It should be entirely absent from the injected water or present only at low concentrations in the displaced water.
3. It must not react with the injected or displaced waters to form a precipitate.
4. It must not be absorbed by the porous medium.
5. It must be cheap and readily available.

To these requirements should also be added the requirement that the tracer must not undergo such physi-

cal or chemical change during passage through the ground as to impair the degree of precision of detection. The ideal tracer, then, may be described as an easily detected substance that will correctly describe the velocity variations of the traced liquid without in any way modifying the transmission characteristics of the liquid porous–medium system.

Water tracers may be conveniently classified according to the method employed for their detection. These methods include the chemical determination and resistivity measurement, the application of direct colorimetry (such as with organic dyes), the detection of nuclear radiations, and such physical measurements as would be involved in mass spectrography or in detecting surface tension changes.

Chemical Tracers and Dyes

Perhaps the best known and most significant investigation of ground water tracers are the underflow studies of Slichter (*1, 2*) reported in 1902 and 1905. The "salt velocity method" and "electrical method" used by Slichter entailed the installation of an upstream, or salt, well and one or more observation wells located in the estimated direction of ground water travel. A solution of several pounds of strong electrolyte, usually sodium chloride, was charged into the upstream well, and the arrival of the tracer at the downstream well was ascertained either by a chloride determination or by the continuous recording of resistivity. The electrical method, which employed resistivity measurements, eliminated the influence of sampling on the ground water gradient in the vicinity of the observation wells. The salt velocity or resistivity procedure is applicable to underflow measurements in relatively permeable materials and for distances of 25–50 ft. Media of low permeability often contain a significant clay fraction and the addition of electrolyte to such materials will generally act to coagulate or disperse the soil colloids, with attendant changes in permeability. An additional factor, restricting the application of Slichter's salt procedure to short distances, is the likelihood of tracer-induced density currents and a distortion of the normal flow pattern.

Experiences with numerous other chemical tracers have been reported in the literature of the water and petroleum industries. Much of this work was carried out on field installations not permitting careful control of the determining parameters, with the result that many of the reports offer conflicting opinions as to the adequacy of a particular tracer. Boron, for example, either as boric acid or as sodium tetraborate, has been reported as a satisfactory petroleum flood water tracer by Carpenter, Morgan, and Parsons (*3*) and by Heck (*4*), the latter finding boron to be more satisfactory than either fluorescein or the ammonium ion. Greenberg (*5*), however, applied borax concentration of 1,000 ppm to field plots of Hanford fine sandy loam, which is an agricultural soil of California, and found that it failed to penetrate more than 2 ft. Other chemical tracers that have been reported, at one time or another, to be both satisfactory and unsatisfactory, depending on test circumstances, include dextrose, dichromate ion, lithium, nitrate, bromoform, and a commercial detergent. It becomes apparent that no single tracer is likely to perform ideally in more than a limited number of situations. Organic materials are likely to undergo microbial decomposition. Cationic materials, particularly sodium, calcium,

and similar positively charged substances, are likely to be removed from solution by ion-exchange reactions. Anionic and nonionic tracers, such as iodine and certain organic materials, may undergo physical adsorption by the medium and exhibit characteristic adsorption isotherms. Substances added to the ground water stream in concentrations sufficient to overcome the adverse effects of adsorption or ion exchange are likely to create density distortions.

The most frequently employed dye for tracing ground water is sodium fluorescein, the sodium salt of resorcinalphthalein. Commercial fluorescein, or uranin as it is often termed, is highly water-soluble and in alkaline solution may be detected by its fluorescence in concentrations as low as 0.1 parts per billion (ppb). In the early years of this century, fluorescein was rather thoroughly studied by a group of French investigators. This work was described by Dole (*6*) in 1906 and more recently by Ambrose (*7*). Dole reported that highly organic soils were observed by the French to adsorb fluorescein while sandy and clayey materials exerted little or no adsorbtive effect. The particular characteristic of soils bringing about the adsorbtive loss was not determined. Another limitation of this dye is its characteristic of changing fluorescence with hydrogen ion concentration. A rise in a pH from 4.6 to 8.0 will produce a fourfold increase in fluorescent intensity; little additional change occurs above pH of 8.0. Although it is generally agreed that fluorescein is a more satisfactory ground water tracer than eosine, methylene blue, fuchsin, or Congo red, its failure has been repeatedly reported, and it is evident that the dyes, like certain inorganic chemical tracers, generally have definite limitations. Fluorescein, and many of the chemical tracers, will perform adequately in highly permeable granular strata or in fissured or cavernized formations, but cannot be relied upon in highly organic or clayey materials of relatively low permeability.

Radioactive Tracers

The use of radioisotopes affords an extremely sensitive means of measurement and permits the detection of tracers in extremely low concentrations. The radioisotope may be incorporated into a wide variety of organic and inorganic compounds, thus enabling the application of tracer materials which would otherwise be difficult to detect by quantitative chemical methods. The employment of radioactive tracers to the study of underground water movement has been primarily confined to the petroleum industry. The radioisotope of iodine, I^{131}, has been used at several installations to evaluate the secondary recovery of oil by water flooding, and has been reported to constitute a satisfactory flood water tracer. Ready availability, low cost, and minimal health hazard are probably major factors accounting for its many applications. The few applications of radioelements to ground water investigations which have been reported in the literature, however, have been primarily concerned with only qualitative evaluation of water movement.

The use of rubidium-86, as the chloride, was reported by Fox (*8*) to have been successful for verifying the source of seepage water during investigation of a reservoir site in Egypt. Rubidium, in this instance, was observed to travel as far as 7 miles, but only qualitative interpretation could be made of the re-

sults obtained. Ruthenium-103, as the ruthenate anion, has been observed to pass through clay columns and to penetrate a considerable distance through natural soil.

Movement Through Porous Media

If a pollutant, tracer, or other inert identifying material is added to the water present in an underground formation, the direction and average rate of travel will be largely dependent on the vector quantity describing the maximum potential gradient. This may be computed from Darcy's law. The variation in velocity from point to point, however, will cause some portions of the fluid to move at greater velocities than others. The result is a "laminar mixing" of the injected or traced fluid with the displaced fluid, so that a "front," or concentration gradient, is established along the direction of flow. The formation of a front in a column of porous media is depicted graphically in Fig. 1. The ideal tracer enters at concentration c_0, but, as the traced fluid progresses through the column, the depth of the front increases in proportion to the distance traveled. It is convenient to plot the average tracer concentration in any lamina taken transverse to the direction of flow as a dimensionless ratio, c/c_0, and this practice will be employed throughout this article. A variety of factors can be considered to influence the depth of a concentration front. In an ideal, homogeneous, isotropic medium, local velocity variations stem from the occurrence of velocity distributions within single pores, the variation of velocity from pore to pore, and the joining and dividing of stream lines caused by the frequent interconnections between passages. In a natural porous medium, the presence of discontinuous

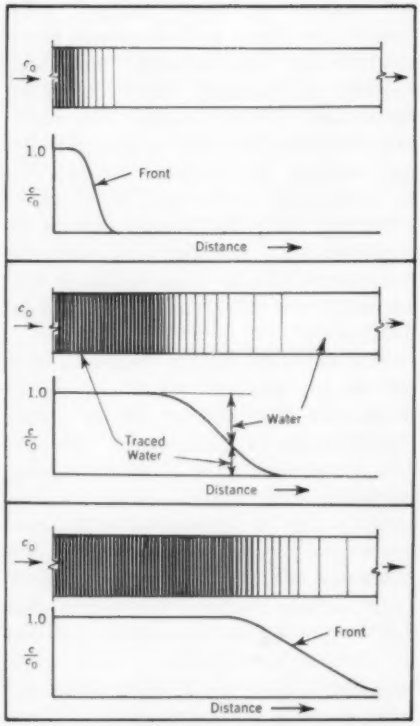

Fig. 1. "Laminar Mixing" in Flow Through Porous Media

The tracer enters at a concentration of c_0. *The ratio* c/c_0 *is a dimensionless quantity which represents the average tracer concentration in any lamina taken transverse to the direction of flow.*

capillaries, impermeable lenses, fissures, and solution cavities serves to bring about further gross velocity variation.

If a liquid containing a trace component enters a porous medium having the capacity to adsorb the component, a separation of the intruding liquid and the tracer occurs. Liquid and tracer fronts will move at different rates, the distance between them increasing with the distance traversed, as illustrated by

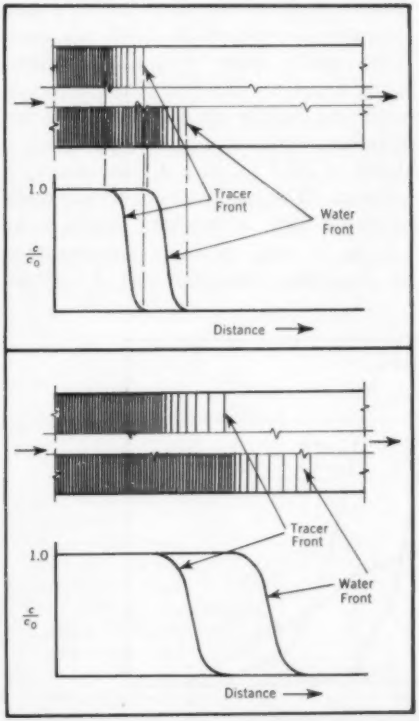

Fig. 2. Retardation of Tracer Front by Ion Exchange or Adsorption

The separation of the intruding liquid and the tracer occurs because of the adsorbing medium.

Fig. 2. If the tracer is added as a transient concentration, or "slug," a similar phenomenon occurs.

For cationic tracers, either chemical or radioactive, the ratio of the velocity of the retarded tracer front to that of the liquid may be computed, provided that an equilibrium between the solid and liquid phases is assumed to be reached almost instantaneously. The formulation of Vermeulen and Hiester (*9*), as developed for organic resins, may be considered as generally applicable to soil systems and will serve to explain why cationic materials are not likely to act as satisfactory tracers. This expression defines the ratio of the tracer velocity, u_A, to the liquid velocity, U, as:

$$\frac{u_A}{U} = \frac{1}{1 + \frac{q_A \rho_b}{c_A f_E}} \quad \ldots\ldots (1)$$

in which q_A is the partial exchange capacity of the medium for the trace component, c_A is the initial concentration of the tracer in the liquid, ρ_b is the bulk density of the porous medium, and f_E is the porosity ratio. If the medium is a coarse granular material having a negligible exchange capacity, q_A will be zero, u_A/U will be unity, and the two fronts will move as one. If a radioactive material is used as a tracer in a medium having an exchange capacity for the element of which the tracer is an isotope, the tracer will undergo exchange sorption even though no great change in concentration of the parent element occurs.

An example will serve to illustrate the implication of Eq 1 in the use of radioactive tracers. Let it be assumed that the radioisotope calcium-45 was added to a water containing 2 milliequivalents (meq) per liter of calcium, and the solution was passed through a medium having an exchange capacity for calcium of 10 mg per 100 g, a porosity of 40 per cent, and a bulk density of 1.59 g per cubic centimeter. In this case, according to Eq 1, the calcium-45 tracer would be expected to move at an average velocity of only one-third that of the water.

It is apparent that radioactive tracers which are exchangeable between solid and liquid phases may be generally unsatisfactory. It should be

noted, however, that, because radioactive isotopes are chemically identical to the stable element, the accompaniment of the tracer by sufficient concentration of the stable or "carrier" isotope may increase the tracer's effectiveness.

California Soil Studies

Laboratory studies were carried out with several tracers and four typical California soils, whose characteristics are shown in Table 1. The Oakley sand, Yolo sandy loam, and Hesperia sandy loam were screened, placed in 3-ft diameter lysimeters, and allowed to consolidate under their own weight. The initial depth of dry soil in each lysimeter was 3 ft, the final depths were 2.9 ft, 2.5 ft, and 2.4 ft, respectively. The lysimeters were operated with tap water and conditioned for several months prior to the tracer runs. With the soils submerged below approximately 1 ft of water, the hydraulic gradient on all lysimeters was maintained constant at 1.3 ft per foot. Yolo sandy loam was also studied, using two 4-in. diameter lucite columns with soil depths of 48.0 and 25.5 in. Hanford loam was investigated at a depth of 33.1 in. in a 4.5-in. diameter column. The laboratory columns were operated with a synthetic water containing a total cationic concentration of 5.12 meq per liter and a sodium ratio of 0.50 to 1. The chlorides and sulfates of sodium, potassium, calcium, and magnesium were employed. In all cases, to avoid ion exchange–induced permeability variations during the tracer application, the proportions of the various cations were held constant and equal to that of the equilibrating water.

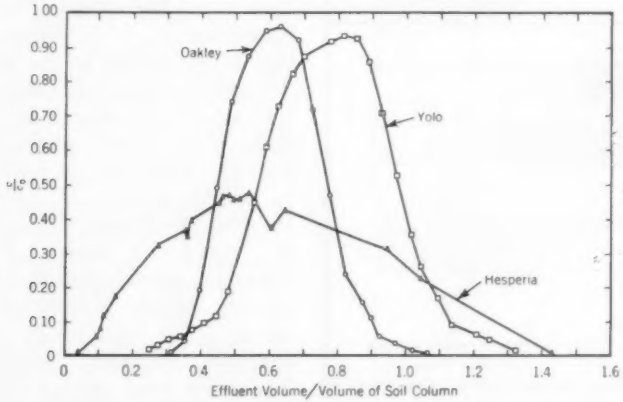

Fig. 3. Comparison of the Passage of Chloride Tracer Through Agricultural Soils

The Hesperia soil had the highest clay and silt content and had the widest particle size distribution. It also exhibited the greatest degree of short-circuiting.

The principal tracers studied with the three lysimeters were chloride, sodium fluorescein, and iodine-131 (as the iodide). Additional runs were

made with the Yolo lysimeter using dextrose, stable calcium, and radioactive calcium-45. Prior to each tracer run, the desired quantity of tracer was mixed with the water covering the soil. The influent was then shut off and the tracer permitted to enter the soil column. Immediately on its complete penetration into the soil, the influent valve was opened, permitting the head to return to normal and forcing the transient tracer concentration through the column. The results of several lysimeter runs are shown in Fig. 3 and 4, and a comparison of the rates of passage of chloride, fluorescein, and iodine-131 through the three lysimeters is presented in Table 2.

It is apparent from Fig. 3 that each soil represents a unique hydraulic entity when measured in terms of the passage of the chloride tracer front. Hesperia loam, containing the largest clay and silt fractions and having the widest particle size distribution, exhibited the greatest degree of short-circuiting. Oakley and Yolo soils displayed relatively sharp fronts, indicative of little short-circuiting. Because the tracers were added as transient concentrations, the breakthrough front and the receding or elution limb were not separated and the normalized effluent tracer concentrations did not reach unity.

Transient tracer curves for Yolo loam, shown in Fig. 4, are representative of the relative positions of the chloride, iodine-131, and fluorescein curves observed with each of the three lysimeters. In this instance, as with all soils investigated, the chloride front was the first to appear in the effluent and is presumed essentially to have moved with the water. Fluorescein was far from satisfactory, the effluent volume corresponding to its initial breakthrough being the greatest of the three tracers. The apparent recovery of fluorescein in excess of 100 per cent

TABLE 1

Characteristics of Soil Systems Studied

Characteristic	Oakley Sand	Yolo Sandy Loam	Hesperia Sandy Loam	Hanford* Fine Sandy Loam
Particle size—*per cent of total make-up*				
Clay, <0.002 mm	5	3	8	(6)
Silt, 0.002–0.05 mm	9	19	30	(21)
Sand, 0.05–0.1 mm	15	20	12.5	(16)
Sand, 0.10–0.125 mm	26	33	17.5	(25)
Medium sand, 0.125–0.5 mm	42	24.5	27.5	(29)
Coarse sand, >0.5 mm	3	0.5	4.5	(3)
Effective size—*mm*	0.020	0.021	0.002	(0.0074)
Uniformity coefficient	11.2	8.1	67.3	(24.9)
Exchange capacity—*meq/100 g*	3.0	14.4 (22.4)	8.9	(6.4)
Carbon content—*per cent*	0.06	0.41	0.33	—
Permeability—*Darcys*†	82	16 (0.02–0.08)	2.2	(6.6)

* Quantities in parentheses refer to soils studied in the lucite columns. Other data apply to lysimeters.
† 1 Darcy = 2.74 ft per day under a unit hydraulic gradient at 20°C.

was attributed to changes in fluorescence brought about by an increase in the pH of the water during passage through the lysimeters. Maximum recovery of iodine-131 was 44 per cent in the Oakley soil, and the tracer losses were found to be roughly proportional to the clay and silt fractions of each soil. It is also probable that the lower flow rate through the Hesperia lysimeter provided time for the additional adsorptive loss of iodine.

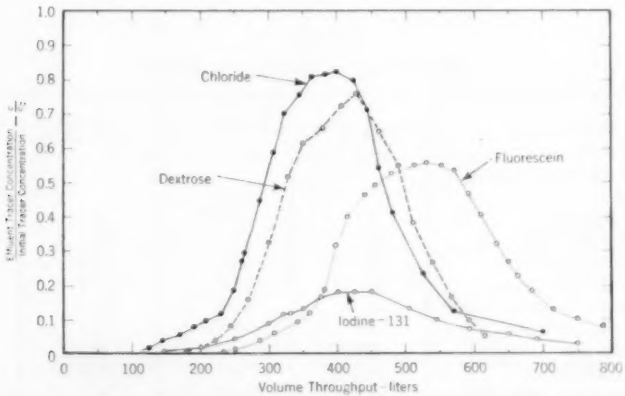

Fig. 4. Comparison of the Passage of Several Tracers Through Yolo Sandy Loam

The "volume throughput" readings indicate the volume of influent which has passed through the column. The lysimeter soil column for the Yolo sandy loam had a 3.0-ft diameter and was 2.5 ft long.

The results of passing a calcium-45 tracer through the Yolo lysimeter are particularly illustrative of the unsatisfactory nature of cationic radioisotopes as ground water tracers. In passing a solution of 11,900 counts per minute (cpm) per milliliter of calcium-45 through the column, together with 100 ppm of chloride and 40.4 ppm of calcium, only 0.16 per cent of the radiocalcium appeared in the effluent even though virtually 100 per cent of the calcium and chloride were recovered. On examination of the soil, the calcium isotope was found to be concentrated about 3 in. below the surface and was moving through the column at a rate of about 1 per cent of that of the water. This experiment served to confirm the applicability of Eq 1 in accounting for the failure of cationic radioactive tracers.

Effects of Stable Iodine

The adsorptive loss of certain radioactive tracers has been indicated to be a function of the concentration of the stable or carrier form of the element present in the liquid phase. The influence of carrier iodine on the passage of iodine-131 through a lucite column of Hanford loam is shown in Fig. 5.

TABLE 2

Comparison of Passage of Chloride, Fluorescein, and Iodine-131 Through Three Soil Lysimeters

Tracer	Initial Tracer Concentration, c_0 ppm*	Fractional Volume Passing		Tracer Recovery per cent	Column Flow Rate ml/min/cm²
		c/c_0 = Trace	c/c_0 = 0.10		
Oakley Sand					
Chloride	153	0.32	0.36	89	0.82
Iodine-131†	2,290 cpm/ml	0.33	0.43	44	0.96
Fluorescein	183	0.35	0.47	138	0.68
Yolo Sandy Loam					
Chloride	183	0.38	0.46	100	0.21
Iodine-131†	2,810 cpm/ml	0.30	0.61	33	0.18
Fluorescein	47	0.46	0.68	170	0.23
Hesperia Sandy Loam					
Chloride	158	0.05	0.11	100	0.024
Iodine-131†	3,090 cpm/ml	0.07		15	0.030
Fluorescein	28	0.07	0.13	130	0.020

* Unless otherwise noted.
† Initial tracer concentration for iodine-131 is given in counts per minute at approximately 50 per cent counter efficiency.

During each radioiodine run, the chloride tracer, together with carrier iodine and in concentrations ranging from 1 ppb to 2 ppm, was also added. Although the chloride front remained unchanged, the radioiodine front was greatly retarded at low carrier iodine concentrations. Because the iodine concentrations in most potable waters are generally less than 10 ppb, it is unlikely that carrier-free iodine-131 will constitute a satisfactory tracer. A nominal amount of any soluble iodide salt would probably make the use of radioiodine feasible, however.

Tritium Studies

Tritium (T), the only radioisotope of hydrogen, has a mass number of 3 and decays by pure beta emission with a half-life of 12.5 years. Natural tritium is produced at a constant rate in the earth's atmosphere as a result of neutron bombardment of nitrogen atoms. High-energy cosmic radiation may cause direct atomic disintegration with the formation of tritium. Its application to meteorologic and hydrologic investigations has been reported by Libby (*10*). The world-wide tritium content of land rainfall has been estimated by Libby as 3.3 tritium atoms per 10^{18} hydrogen atoms, a radioactivity concentration equal to 10^{-5} microcurie (μc) per liter. The measurement of the natural tritium content of ground waters offers a means of estimating the period of time such waters have been in the ground and may prove a valuable tool to the ground water

hydrologist. Unfortunately, the measurement of tritium concentrations of less than 10^{-5} μc per liter poses a difficult counting problem for which commercial counting equipment is only now becoming available.

The application of artificially produced tritium, as tritiated water (HTO), to ground water measurements was investigated with the lucite columns of Yolo and Hanford loam. temperature, it was possible to obtain reproducible assays. Each sample was counted for at least three 10-min intervals and the maximum counting rate was recorded as the equilibrium value. The efficiency of this counting procedure was only 0.05 per cent.

The results of five chloride-tritium runs are shown in Fig. 6 and 7. It is immediately apparent that the tritiated water moved at a lower velocity than

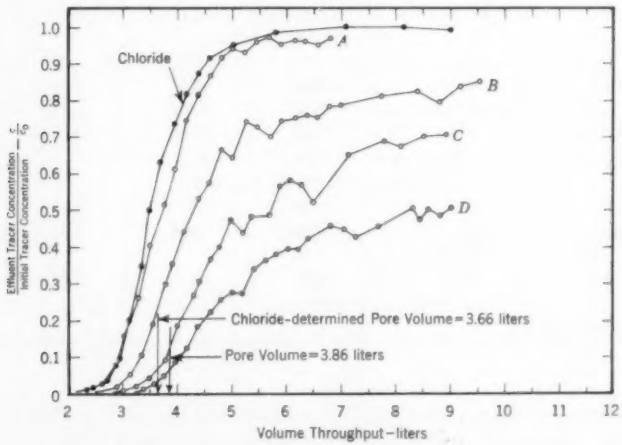

Fig. 5. Influence of Stable Iodine on Passage of Iodine-131 Through Hanford Loam

Curves A-D *indicate data for the following concentrations of stable iodine added to the iodine-131 solutions:* A—*2 ppm;* B—*100 ppb;* C—*10 ppb; and* D—*1 ppb.*

Concentration fronts obtained with chlorides and tritiated water on these two materials are shown in Fig. 6 and 7. Tritium fronts were determined by counting 4-ml samples of the column effluents in 1.75-in. diameter aluminum pans. The samples were placed in the chamber of a 3-in. diameter proportional flow counter operating at 4,800 v with methane gas. By carefully regulating the gas flushing rate and operating the counter chamber at a constant the chloride tracer. On closer examination of the Yolo soil data it may be concluded that the extent of retardation, measured in volume or in time, is directly proportional to the length of column traversed by the front. A rigorous interpretation of Fig. 6 requires a more detailed analysis of the chloride front and its relation to the pore volume of the column. The total pore volume of each column was calculated by determining the specific gravity of

each medium and adding a weighed amount to a known gross column volume. The pore volume occupied by displaceable water can be conveniently calculated from the expression

$$vf_E' = \int_0^V (1 - c/c_0)dV \ldots (2)$$

in which vf_E' is the volume of the liquid contained in the column and V is the volume of liquid necessary to displace vf_E'. Equation 2 may be evaluated by a graphical integration of the area above the chloride front. For example, the chloride-determined pore volume of the 48-in. Yolo column was 4.47 liters while the total pore volume was 5.75 liters. The difference, 1.28 liters, equals the volume of entrained air plus nonconnected pores.

The area between the chloride and tritium fronts may be interpreted as equal to the volume of "exchangeable water," or "solid water," associated with the medium. Chloride tracer is assumed to have entered all connected pores containing free water. It is probable, however, that the tritiated water molecules also entered the media granules, replacing water adsorbed on the surface of clay minerals present or between the unit cell layers of the clay colloids. Also, exchange probably occurred between the tritiated water and water adsorbed as dipoles on the exchangeable cations sorbed on the clay minerals. The quantity of exchangeable water in kaolinite, attapulgite, and bentonite clays was measured by Faucher and Thomas (*11*) by using heavy water (D_2O) and found to range from 0.0 to 18.9 per cent, being generally less than that lost on ignition. Exchangeable water, on an oven-dry

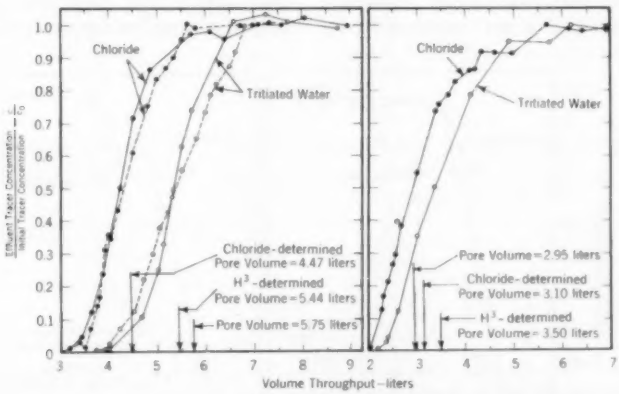

Fig. 6. Passage of Chloride and Tritium Tracers Through Yolo Sandy Loam

For the 48-in. column, solid lines indicate data for chloride and HTO tracers moving at a rate of 35 ml/hr, and the broken lines indicate data for a rate of 8.8 ml/hr. For the 25.5-in. column, both chloride and HTO tracers moved at a rate of 30 ml/hr.

weight basis, was calculated to be 7.1 per cent for the Yolo loam and 0.96 per cent for the Hanford loam.

In media low in clay and silt, the retardation of tritiated water would not be significant. Since this same statement can be made for iodine, however, it would seem that tritium gives little advantage in tracing water movement. On the other hand, it should be noted that these data do not entirely negate the value of natural tritium measurements because, if a soil were continuously charged with tritium, a state of equilibrium would be achieved and retardation would probably be negligible.

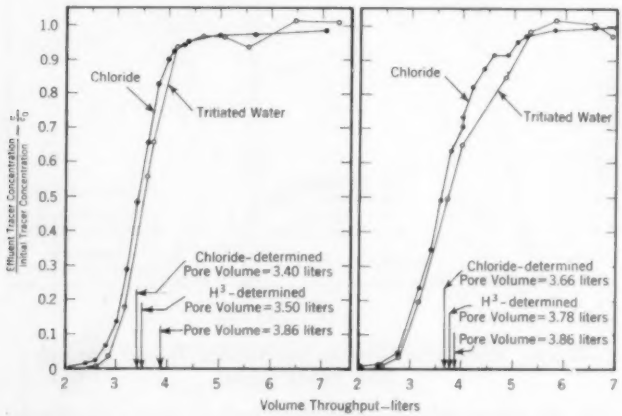

Fig. 7. Passage of Chloride and Tritium Tracers Through Hanford Loam

The data are for tracers moving at a rate of 800 ml/hr.

Field Studies

During the course of an investigation of pollution travel by the University of California's Sanitary Engineering Research Laboratory, it was desired to determine the direction and rate of travel of a recharge water front. Included in the study was a preliminary field evaluation of fluorescein, chloride, dextrose, and iodine-131. The tracers were injected through a 12-in. well into a confined aquifer 90 ft below the ground surface at a rate of 37 gpm. Twenty-three 6-in. diameter, radially placed, observation wells were employed to follow the tracer front and to define the piezometric surface during recharge. The aquifer averaged 4.4 ft in thickness and was composed primarily of pea gravel and sand having an effective size of 0.56 mm and a uniformity coefficient of 6.9.

The heavy dose of sodium chloride required to provide a detectable chloride concentration at the 500-ft observation well brought about a density separation of the tracer in the vicinity of the injection well and the sporadic arrival of the tracer at the observation wells. Fluorescein tracer was introduced into the aquifer by the injection of 450 gal of a 110-ppm solution of sodium fluorescein. Twenty pounds of sugar at a concentration of 6,000 ppm were introduced in a similar manner.

Twenty millicuries of carrier-free iodine-131 were introduced over a 3-min period at the normal injection rate. A summary of the arrival times at three observation wells situated along a southerly meridian through the injection well is shown in Table 3. Coliform bacteria arrival data obtained in a similar manner are also shown.

The tracer travel data suggest extreme fingering or short-circuiting and indicate that the maximum rates of recharge water travel greatly exceeded the average rate. Iodine-131 was the least satisfactory tracer by comparison with dextrose and florescein. At a distance of 100 ft from the recharge well, the iodine activity did not exceed 6 micromicrocuries ($\mu\mu$c) per milliliter and was extremely erratic. The peak fluorescein concentration at the 100-ft well was 0.4 ppm and exhibited a trailing elution limb similar to that observed in the lysimeter studies.

TABLE 3

Comparative Travel Times of Various Tracers During Injection Well Operation

Distance from Injection Well—*feet*	Time of Arrival of First Detectable Tracer—*hr*				
	Fluorescein	Dextrose	Coliform Organisms	Iodine-131	Computed*
13	0.2	0.6	0.4	1.1	2.8
63	2.8	8.2	23	29	65
100	15	16	24	75	160

* Computed time of front arrival based on an injection rate of 37 gpm into a confined stratum having an average thickness of 4.4 ft and a porosity of 0.35.

Conclusions

Although the water supply and petroleum literature is replete with accounts of field studies of tracers applied to porous-media problems, little effort has been made to evaluate quantitatively the adequacy of the various tracers from a soil-chemical standpoint. Furthermore, the fundamental physical nature of velocity variations occurring in flow through porous media is not well understood and warrants further study if ground water resources are to be protected from chemical and radioactive pollutants. Considering experiences reported in the literature and the laboratory studies discussed herein, it can be concluded that no single substance is likely to constitute an ideal ground water tracer under all circumstances. Of the dyes available, sodium fluorescein is probably the most satisfactory, but its use should be limited to media free of organic material and of relatively high permeability. Chloride, added in the form of the salts of sodium and calcium, will generally be effective, provided that density currents or permeability variations do not result. Of the radioactive tracers available, only those in the anionic or nonionic form should be considered. Iodine-131, as the iodide, has shown the greatest promise but should be accompanied with several parts per million of stable iodine. Natural tritium offers the ground water hydrologist an untapped opportunity for extensive surveys of underground water movement.

References

1. SLICHTER, C. S. The Motions of Underground Waters. *USGS Water Supply Papers,* No. 67 (1902).
2. SLICHTER, C. S. Field Measurements of the Rate of Movement of Underground Waters. *USGS Water Supply Papers,* No. 140 (1905).
3. CARPENTER, P. G.; MORGAN, T. D.; & PARSONS, E. D. Use of Boron Compounds as Water Flood Tracers. *Producers Monthly,* **16**:12 (Oct. 1952).
4. HECK, E. T. Tracing Fluids Between Wells. *Producers Monthly,* **16**:31 (1954).
5. GREENBERG, A. E. Field Investigation of Waste Water Reclamation in Relation to Ground Water Pollution. Final Report of San. Eng. Research Lab. to State Water Pollution Control Board, Univ. of Calif., Berkeley, Calif. (Jun. 1952).
6. DOLE, R. B. Use of Fluorescein in the Study of Underground Water. *USGS Water Supply Papers,* No. 160 (1906).
7. AMBROSE, A. W. Use of Detectors for Tracing Movement of Underground Water. *US Bureau of Mines Petroleum Tech. Bul.,* No. 195 (1921).
8. FOX, C. S. Using Radioactive Isotopes to Trace Movement of Underground Waters. *Munic. Utilities,* **90**:30 (Apr. 1952).
9. VERMEULEN, T. & HIESTER, N. K. Ion Exchange Chromotography of Trace Elements. *Ind. Eng. Chem.,* **44**:636 (1952).
10. LIBBY, W. F. Research to Assay Rain and Surface Water for Natural Tritium Content. Final Report, Air Force Contract A.F. 18(600)-564, Univ. of Chicago (Jun. 1, 1954).
11. FAUCHER, J. A. & THOMAS, H. C. Exchange Between Heavy Water and Clay Minerals. *J. Phys. Chem.,* **59**: 189 (Feb. 1955).

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Problems in Estimating Fluorides in Water

Harry P. Kramer, Robert C. Kroner, and Dwight G. Ballinger

A paper presented on Jun. 13, 1955, at the Annual Conference, Chicago, Ill., by Harry P. Kramer, Chief; Robert C. Kroner, Chemist; and Dwight G. Ballinger, Chemist; all of the Advanced Training Sec., Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

THE growing practice of fluoridating public water supplies has focused a great deal of professional interest upon the analytical methods available for fluoride determination. A wide range of training and experience is exhibited by the personnel regulating the fluoridation process in the more than 1,000 cities in the United States which now practice fluoridation. What is needed is a simple, foolproof method of determining microquantities of fluoride in water. The desired objective is a specific test that is rapidly and easily performed. In reality, however, a specific reaction is rarely (if ever) achieved with any determination; the most that can be hoped for is a reaction that is highly selective.

A survey of the relevant technical literature reveals that much work has been done on the determination of fluorides in water. Gravimetric and volumetric methods are either unavailable or unsuitable for general use. The more successful procedures are colorimetric methods based on the bleaching action of the fluoride ion on certain organo-metallic complexes (*1–9*). In particular, the action of fluoride on a zirconium-alizarin lake has been intensively investigated and appears to be the best method available at the present time. The current edition of *Standard Methods* (*10*) includes three variations of this zirconium-alizarin reaction—the Scott-Sanchis method, the Lamar method, and the Megregian-Maier photometric procedure.

The ideals for a quantitative colorimetric determination of fluoride include a fast reaction employing a single colorless reagent in sufficient but noncritical quantity. Use of such a reagent should yield an intense color in the presence of microquantities of fluoride; the sensitivity, that is, must be high. The color system should be stable and unaffected by variations in temperature or in pH, and—most important of all—should exhibit no interference by other substances present in the sample. Furthermore, it is strongly preferred that the color development be positive, giving greater color intensity with increasing fluoride concentrations. These ideals will be considered further as they relate to methods currently available for the determination of fluorides in waters.

Comparison of Methods

Close adherence to time and temperature requirements is necessary for the instrumental methods, and for visual methods employing permanent standards, as the sample treatment must exactly duplicate the conditions under which the standards were prepared. This is particularly true for the instrumental methods, in which readings of the samples must be made within ± 2°C and ± 2 min of the conditions of the standards. In visual methods employing temporary standards, the samples and standards are prepared at the same time, so that accurate time and temperature control is not required. In such methods, reagents should be added to standards and samples within a 2-min interval, but the requirement for reading at a precise time or temperature is greatly relaxed, as standards and samples are subject to identical conditions.

Instrumental methods utilizing photometers or spectrophotometers provide the greatest accuracy, but their use may be limited by equipment requirements to the larger and more elaborate laboratories. The use of permanent standards offers convenience and simplicity, usually with some sacrifice in accuracy. Routine checks of standard curves and permanent standards are necessary, and the need for recalibration following preparation of new reagent batches must be strongly emphasized. Frazier (*11*) has reviewed the use of such permanent standards as those offered in the Hellige * and Taylor † comparators, and has discussed in some detail their advantages for fluoride determinations. Based upon limited data, he observed a precision of 0.1 ppm. The US Public Health Service had indicated in some previous evaluations that a precision of 0.2 ppm fluoride was possible with color comparator devices. The use of such proprietary devices for fluoride determination is currently being re-examined by Task Group 2620P—Fluoridation Materials and Methods. The Nessler-tube technique using temporary standards gives good precision, offers the advantages of time and temperature duplication previously mentioned, and does not require that samples be transferred to other vessels for reading.

Interfering Substances

Measurement of fluoride which has been added to distilled water can be accomplished easily by many of the available methods, despite their shortcomings with respect to the ideals previously mentioned. Unfortunately, the reactions lack specificity and respond to the presence of other substances common in water supplies. Free chlorine, manganese, and aluminum have been shown by Taras, Cisco, and Garnell (*12*) to create significant interference in a zirconium-alizarin method. Table 1 presents a comparative listing of several interfering substances for the Megregian-Maier, the Lamar, and the Scott-Sanchis standard methods and for the recently published Megregian Eriochrome Cyanine R method (*9*) at the level required to produce an error of ± 0.1 ppm fluoride at a fluoride concentration of 1.0 ppm. This is based upon a reading time of 1 hr for the three standard procedures, and of 5 min for the ECR method.

Interference values, including details concerning the magnitude of error due to variations in concentrations of both fluoride and interfering substances, are included in *Standard Methods* (*10*). Some of the sources of error may be

* Hellige, Inc., Long Island City, N.Y.
† W. A. Taylor & Co., Baltimore.

recognized and corrected quite easily; for example, the presence of chlorine can be ascertained quickly and destroyed by the addition of sodium arsenite or certain other reductants. Color and turbidity are usually controlled by simple measures, such as compensation in the actual measurement, or filtration. Substances such as sulfate and chloride must be present in sizable concentrations to produce an error equivalent to 0.1 ppm fluoride. Other ions however—such as aluminum, iron, manganese, and phosphate—interfere at low levels.

of ± 0.1 ppm fluoride. When the concentration of fluoride in the sample permits, full advantage should be taken of this practice.

Organic Materials

A type of interference that has not been sufficiently investigated is the effect of organic materials found in surface waters. To examine this question 1 ppm fluoride was added to samples containing 100 ppm of pure organic substances representing types of compounds common to domestic sewage. Measurements employing

TABLE 1

Concentration of Interfering Substances Producing ±0.1-ppm Error at 1.0-ppm Fluoride Level

Interfering Substance	Concentration—*ppm*			
	Megregian-Maier Method	Lamar Method	Scott-Sanchis Method	ECR-Megregian Method
Chloride	1,800	1,000	2,000	3,500
Alkalinity	325	200	400	3,300
Sulfate	400	600	300	40
Ferric iron	5.0	2.0	2.0	40
Aluminum	0.2	0.5	0.25	*
Phosphate	1.0	1.0	5.0	6.0
Hexametaphosphate	1.1	1.0	1.0	2.0

* Varies with time.

The increased use of phosphate compounds in modern household detergents presents a growing problem, not only in water treatment (*13*), but also in fluoride measurement. Phosphates contributed by domestic sewage may be present in raw water and may actually be added in the water treatment plant; even laboratory glassware washed with detergents high in phosphate offers a source of error, if not rinsed sufficiently. The simplest procedure for diminishing interference by phosphate and other ions is to dilute the sample with fluoride-free water until the error resulting from such interference is below the accepted limit

the Megregian-Maier procedure were made, with and without distillation. The results are presented in Table 2. In the case of peptone, addition of the reagent to the undistilled sample caused turbidity, owing to the low pH of the system. Interference by sodium lauryl sulfate was a vagrant phenomenon, positive on undistilled samples and negative on distilled samples. The variation was apparently caused by decomposition of the sodium lauryl sulfate, which appeared as solid matter in the distillate. A raw water sample from Nitro, W. Va., known to contain considerable organic contamination, was examined similarly. Increments

of fluoride could be measured accurately in both distilled and undistilled samples. No difficulty in the distillation process was evident. From this it may be construed that such organic substances, with the exception of the synthetic detergent, do not interfere in fluoride determinations at the levels prescribed. (These levels, incidentally, greatly exceed the concentrations normally expected in waters used for domestic purposes.)

TABLE 2

Effect of Organics on Fluoride Determination (Megregian-Maier Method) *

Organic	Without Distillation *ppm*	With Distillation *ppm*
Urea	1.00	0.96
Peptone	1.32	0.90
Sodium lauryl sulfate	1.28	0.75
Glucose-glutamic acid	1.00	0.96
Phenol	1.00	0.90

* Samples contain 100 ppm organic and 1 ppm fluoride.

Where interfering ions are not easily destroyed and where dilution of the sample is not feasible as a remedial measure, separation is necessary. In the case of fluorides the accepted separation process involves distillation of fluoride as hydrofluosilicic acid from a strongly acid solution with steam and heat. Frazier and Oldfield (*14*) have proposed a method of rapid distillation by addition of the sample at a constant rate to a boiling sulfuric acid solution. The steam distillation technique has been examined by Megregian and Solet (*15*) and is included in *Standard Methods*.

Distillation Techniques

When distillation is used in the separation of interfering substances, precautions must be taken to prevent further errors resulting from the remedial procedure itself—volatile acids, for example, may be a source of error. Suitable quantities of Ag_2SO_4 added to the distillation flask will take care of any hydrochloric acid present. Nitric and nitrous acid in sufficient concentration to cause interference would be encountered rarely. Considerable potential error exists, however, in the carryover of sulfuric acid during distillation. Significant acidity of the distillate can be caused by: [1] too high a distillation temperature, [2] too rapid a distillation rate, [3] overheating of the flask surface above the liquid level, or [4] improperly assembled equipment. Figure 1 illustrates the pronounced effect of low pH upon the fluoride readings. The error exceeded 0.1 ppm fluoride below pH 2.5

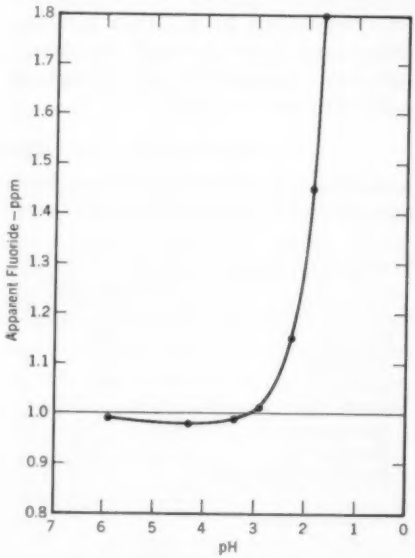


Fig. 1. Effects of Acidity on Fluoride Readings

The effect of low pH on color formation readings is pronounced. 1.0 ppm fluoride was added to Megregian-Maier reagent, pH decreased by controlled addition of H_2SO_4.

and increased rapidly for lower pH values.

The judicious choice of volumes for both the initial sample and final distillate will aid the analyst in arriving at an accurate fluoride result. Using a 50-ml sample and 150 ml of distillate establishes a lower limit of concentration (0.6 ppm fluoride) which may not be passed without concentration of the sample. The multiplication factor of 3 existing between the two volumes raises significantly any error produced in the distillation or resulting measurement. At the sacrifice of a few additional minutes of distillation time, the use of a 100-ml sample, from which 200 ml of distillate is recovered, offers advantages. The necessity for concentration of samples with low fluoride values is decreased, and the multiplication factor is lowered to a value of 2.

Other methods of distillation and color formation have been proposed. Thrun (*5*) has developed a distillation technique in which air, instead of steam, flows rapidly through the heated distillation flask. In his color development procedure, the reagent (composed of a buffered solution of aluminum and ECR) permitted measurement within 10–15 min. Megregian (*9*) has investigated other reagent possibilities and suggests a zirconium-ECR solution in strong hydrochloric acid. A spectrophotometer is desirable for measurement of this color system because of the need for a narrow-band pass. Stability is quickly established and readings may be taken after 5 min. This method shows little sensitivity to common interfering substances (with the exception of sulfate). A simple turbidimetric procedure for sulfate determination and a nomogram for correction of the fluoride reading are included. The speed of this reaction suggests potential use

TABLE 3

Fluoride Results Obtained by Trainees

Lamar Method		Megregian-Maier Method		Lamar Method		Megregian-Maier Method	
50-ml Aliquot *ppm*	100-ml Aliquot *ppm*	50-ml Aliquot *ppm*	100-ml Aliquot *ppm*	Non-distilled *ppm*	Distilled *ppm*	Non-distilled *ppm*	Distilled *ppm*
Sample *A*—0.25 ppm F^-				Sample *C*—0.75 ppm F^- + 20 ppm PO_4^{---}			
0.2	0.2	0.28	0.26	1.0	0.8	2.64	0.68
0.4−	0.2+	0.13	0.25		1.2	2.6	0.7
0.3	0.3	0.13	0.25	1.0	0.8	2.88	0.77
0.2	0.2	0.28	0.29	1.04	0.80	2.8	0.88
0.4	0.3	0.20	0.24	0.7	0.7		0.62
0.2	0.2	0.28	0.26	1.0	0.6		
Sample *B*—1.05 ppm F^-				Sample *D*—1.25 ppm F^- + 5 ppm Al^{+++}			
1.0	1.0	1.14	1.10	1.0	1.2	0.52	1.22
1.0	1.0	1.10	1.08		1.2	0.4	1.06
1.0	1.0	1.18	1.12	0.9	1.2	0.5	1.20
1.1	1.1	1.00	1.08	0.72	1.3	0.64	1.4
1.0	1.0	1.04	1.06	0.5	1.2	0.43	1.22
1.0	1.1	1.08	1.04	1.0	1.0		

for continuous, automatic fluoride measurement. Morris and Cerny (*16*) propose an air distillation technique with carefully controlled air flow, in which rapid distillation is coupled with recovery of the undiluted sample. This feature would, in many cases, lessen the requirement for preliminary concentration of the sample.

A number of short training courses in the examination of waters for fluorides have been conducted in the past few years by the US Public Health Service. These courses have been presented both at the Robert A. Taft Sanitary Engineering Center and, at the request of state health departments, in several state centers, for health department and water works personnel.

In these courses four different synthetic samples are analyzed by the trainees. Samples *A* and *B* are simple fluoride solutions in distilled water, while samples *C* and *D* include interfering substances. The concentrations of fluoride in the samples are unknown to the trainees. Table 3 shows results obtained in one of these courses. It is apparent from the values obtained on samples *A* and *B* that measurement can be made readily within ± 0.1 ppm fluoride by inexperienced persons. For the distilled samples, 100 ml was taken, and 200 ml of distillate collected, which was then divided for measurement by both the visual and instrumental procedures. These results indicate good performance on both distilled and nondistilled samples. Variations may be assumed to be a result of the distillation process, as the methods of color development and measurement are identical.

References

1. Sanchis, J. M. Determination of Fluorides in Natural Waters. *Anal. Chem.*, **6**:134 (1934).
2. Scott, R. D. Modification of the Fluoride Determination. *Jour. AWWA*, **33**:2018 (Nov. 1941).
3. Lamar, W. L. Determination of Fluorides in Water: A Modified Zirconium-Alizarin Method. *Anal. Chem.*, **17**:148 (1945).
4. Megregian, S. & Maier, F. J. Modified Zirconium-Alizarin Reagent for Determination of Fluoride in Water. *Jour. AWWA*, **44**:239 (Mar. 1952).
5. Thrun, W. E. Rapid Methods for Determination of Fluoride in Waters. *Anal. Chem.*, **22**:918 (1950).
6. Price, Margaret J. & Walker, Osman J. Determination of Fluoride in Water. *Anal. Chem.*, **24**:1593 (1952).
7. Levinson, David & Harley, John H. Spectrophotometric Determinations of Fluoride Ion. *Anal. Chem.*, **25**:794 (1953).
8. Powell, W. Allan & Saylor, J. H. Fluorometric Determination of Small Amounts of Fluoride. *Anal. Chem.*, **25**:960 (1953).
9. Megregian, S. Rapid Spectrophotometric Determination of Fluoride With Zirconium-Eriochrome Cyanine R Lake. *Anal. Chem.*, **26**:1161 (1954).
10. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA, & FSIWA, New York (10th ed., 1955). p. 98.
11. Frazier, R. E. Use of Permanent Standards in Fluoride Analysis. *Jour. AWWA*, **47**:560 (Jun. 1955).
12. Taras, M. J.; Cisco, H. D.; & Garnell, M. Interferences in Alizarin Method of Fluoride Determination. *Jour. AWWA*, **42**:583 (Jun. 1950).
13. Smith, R. S.; Cohen, J. M.; & Walton, Graham. Effects of Synthetic Detergents on Water Coagulation. *Jour. AWWA*, **48**:55 (Jan. 1956).
14. Frazier, R. E. & Oldfield, H. G. Rapid Method for Distilling Fluorides From Water Samples. *Public Health Repts.*, **68**:729 (1953).
15. Megregian, S. & Solet, I. Critical Factors in Fluoride Distillation Technique. *Jour. AWWA*, **45**:1110 (Oct. 1953).
16. Morris, R. L. & Cerny, Josephine. Fluoride Distillation Method Using Controlled Air Jet. *Jour. AWWA*, **48**:449 (Apr. 1956).

Demineralization of Brackish Water for Potable Supply at Matagorda Island

Robert S. Y. Yoseph

A contribution to the Journal by Robert S. Y. Yoseph, Project Engr., Office of the AF Installations Representative, US Dept. of the Air Force, Boston, Mass.

THE water supply for Matagorda Island, a bombing and gunnery range located in the Gulf of Mexico off Port O'Connor, Tex., is obtained from a deep well on the island. The well, drilled in February 1951, is 305 ft deep and gravel packed, with a stainless-steel screen extending from the 266-ft level to the bottom. It is equipped with a 230-gpm pump. An analysis of water obtained from this well is provided in Table 1.

Prior to 1951, the water supply for domestic purposes was obtained from shallow wells. These wells, however, had to be abandoned because of increasing chloride content. (At the time of their abandonment, the average chloride content was over 2,000 ppm.)

While the deep well was being drilled, action was initiated to procure two thermocompression distillation units. It was learned that two 300-gph units in Bermuda, owned and operated by the Army Engineers since 1941, were available for transfer to Matagorda Island. A previous study had indicated that these units could be shipped to the manufacturer and modernized at a total cost of $6,500; new units of comparable capacity would at that time have cost $17,000 each. Assurances were received from the manufacturer that after the necessary modifications the units would be quite similar to the new models.

Thermocompression Distillation

As the name implies, thermocompression distillation is a process intended primarily to distill water containing salt and impurities for the purpose of extracting pure water. The system is designed for continuous operation and produces a constant output of distilled water. It requires a continuous blowdown of concentrated impurities to waste. The raw water is boiled or evaporated by the heat of the steam on the outside of the tubes. The pure vapor formed is drawn off, compressed by a vapor compressor, and condensed in the steam duct, from which it flows (as water) through a heat exchanger (cooler) and out of the unit. A diesel engine provides power to drive the vapor compressor and the pumps, as well as heat to start the system and to compensate for operating heat losses.

The thermocompression distillation units were delivered and put into operation in March 1951. From the outset, they were a continual source of trouble to the operating personnel. In spite of a combined capacity of 600 gph, it was a matter of some anxiety for 2½ years whether enough water could be distilled for the cooking and drinking needs of a base complement of only 300 persons. The initial design was based on an average consumption

of 5 gpcd, which was considered to be quite generous, inasmuch as drinking water was piped only to the consolidated mess hall. The failure of the units to deliver sufficient quantities of distilled water was caused by two major factors: mechanical troubles and the scaling of heat exchangers.

The mechanical failure may be largely attributed to the diesel engine, which was a discontinued model, so that only through special orders could replacement parts be obtained. The scaling of the evaporative tubes, however, was by far the most unsatisfactory aspect of the entire system. The units could not be operated for more than 150 hr without requiring descaling—and, consequently, shutdown. Niter cake (sodium acid bisulfate), commonly recommended for descaling, was found to be inadequate and the tubes had to be drilled mechanically, which required 6–7 days of tedious work. It was found by experimentation that hydrochloric acid, with a corrosion-inhibiting agent (such as formaldehyde), would readily dissolve the scale. Its use for routine descaling was not recommended, however, because of prevailing safety regulations.

TABLE 1

*Analysis of Deep Well Water, Matagorda Island**

Item	Equivalent	Amount *ppm*
Total dissolved solids		2,430
Total hardness	$CaCO_3$	263
Noncarbonate hardness	$CaCO_3$	0
Bicarbonate	HCO_3	504
Manganese	Mn	0
Silicate	SiO_2	16
Iron	Fe	0.1
Fluoride	F	0.6
Calcium	Ca	46
Magnesium	Mg	36
Sodium and potassium	Na	853
Sulfate	SO_4	74
Chloride	Cl	1,150
Total alkalinity	$CaCO_3$	413

* The pH value is 7.8.

As the units were originally designed to operate on sea water, it was decided to discontinue the use of the well water and use sea water instead. An analysis of the sea water is given in Table 2. Somewhat longer runs were experienced with sea water, and the descaling of the evaporative tube was accomplished more readily by niter cake. Because of mechanical troubles and loss of time for descaling, however, the units were out of operation as much as 15 days each month.

TABLE 2

Analysis of Sea Water Near Matagorda Island

Item	Amount—*ppm*
Calcium carbonate	67
Calcium sulfate	1,592
Magnesium sulfate	2,120
Magnesium chloride	3,770
Magnesium carbonate	trace
Silicate (SiO_2)	143
Sodium chloride	31,635
Total dissolved solids	39,327

Demineralization Equipment

Because the thermocompression distillation units had failed to live up to expectations, it was decided to procure new equipment late in 1952. There were two possibilities:

1. A new 600-gph thermocompression distillation unit equipped with a brine stabilizer might be purchased. The stabilizer is a relatively new device recommended by the US Army. It consists of a large cylinder filled with gravel and sand through which the hot water from the evaporator header is

circulated continuously. This arrangement was reported to increase the cycle of operations up to 3 months without descaling, and would cost about $38,000.

2. Demineralization equipment might be installed, at a cost of $27,000.

Because of the high initial cost and considerable uncertainty associated with the distillation unit it was decided to procure demineralization equipment. As the need for a dependable potable-water supply was urgent, the high operating cost of the demineralization equipment was considered no serious obstacle.

The demineralization plant was designed with the following requirements in mind:

1. The equipment was to fit the existing structure housing the distillation units.

2. The system was to produce 3,600 gal for each 12 hr of operation (including down time).

3. The system was to be completely automatic to permit the use of unskilled military personnel.

As the hardness of the well water supply was relatively high, it was decided to treat the water in a zeolite softener prior to its introduction into the demineralization units. This practice would tend to avoid difficulties arising from sulfation of the cation-exchange material and the resultant decrease of exchange capacity. Although at first glance the inclusion of this zeolite softener might appear to be an additional expense, its cost is more than offset by the decrease in size and improved efficiency of the cation-exchange unit. Details of the system's design are shown in Table 3.

Table 3 indicates that the zeolite softener is of considerably larger capacity than the cation-exchange unit, which, in turn, is of larger capacity than the anion unit. The capacity of each unit was based on the final output requirements of the system as a whole, as well as the requirements of backwashing, rinsing, and preparing regeneration solutions, using waters of various degrees of purification. For example: raw water is used for backwashing and rinsing the sodium zeolite softener; sodium zeolite–softened water is used for backwashing, rinsing, and preparation of the regeneration solution for the cation exchanger; and sodium zeolite–softened water is used for backwash, rinse and preparation of the regenerant for the anion exchanger, with the final rinse accomplished with the cation exchanger effluent.

TABLE 3

Design Characteristics of Demineralization System

Item	Zeolite Softener	Cation-Exchange Unit	Anion-Exchange Unit
Output per unit run—*gal*	16,900	4,560	3,600
Length of run between regenerations—*hr*	24	12	12
Ions in raw water to be removed—*ppm**			
Hardness	263		
Cations		2,140	
Anions			1,710
Exchange capacity per unit run—*kilograins*	260	570	450
Flow rate—*gpm*			
Operating	8	8	8
Design maximum	49	56	56

* As $CaCO_3$.

To obtain 3,600 gal of treated water every 12 hr, the system was designed according to the following time schedule:

1. All units are operated simultaneously for 8½ hr at 8 gpm.

2. The anion and cation exchangers are regenerated in a total time of approximately 210 min.

3. After every two cycles of the demineralization units the sodium zeolite softener is regenerated. (On these oc-

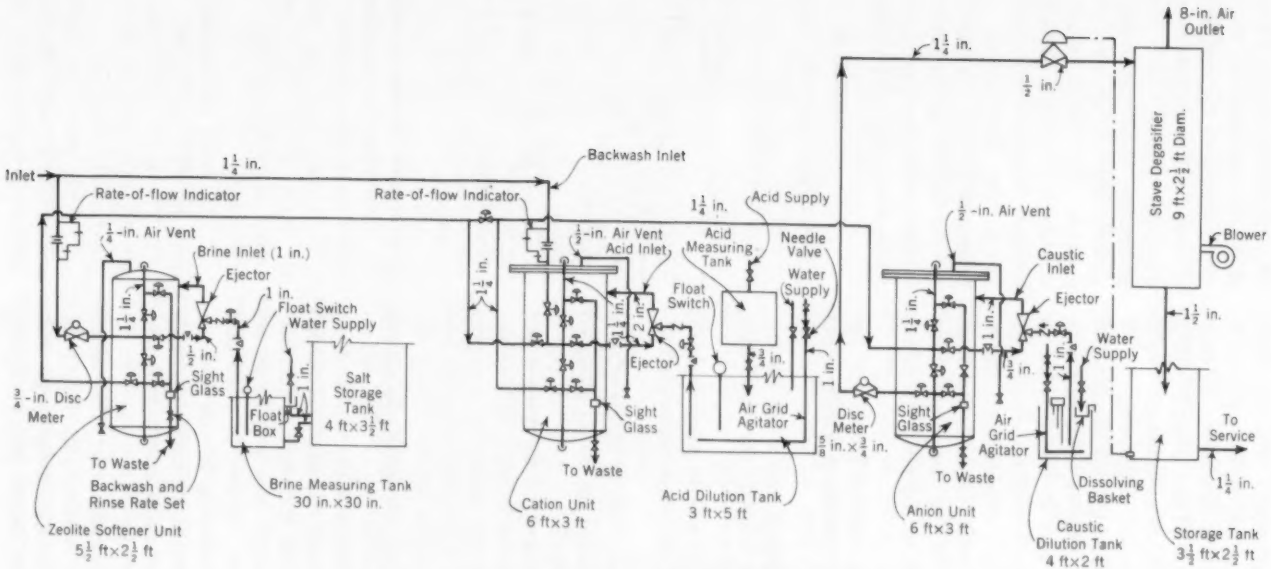


Fig. 1. Schematic Diagram of Demineralization Process

casions the total down time for the system would be 4½ hr. Thus, during one cycle the plant would be in operation for 8½ hr out of 12, and during the second cycle for 7½ hr.)

Construction and Operation

Plans and specifications for the demineralization plant based on the above description were prepared by the technical personnel of the Installations Division, Strategic Air Command, Omaha, Neb. A schematic diagram based on these plans is shown in Fig. 1. The job was advertised for bidding early in 1953 and the contract (including a subcontract for furnishing the demineralization equipment) was awarded in mid-April. The bid price for the job was $27,400. Figure 2 shows a large part of the demineralization equipment used.

Construction was completed by the end of October and the test runs began on Nov. 4, 1953. During the first run, which lasted 11 hr, hourly samples were collected and analyzed. Tests on these showed an average hardness, chloride, total dissolved solids, and CO_2 content of 1, 31, 50, and 1 ppm, respectively.

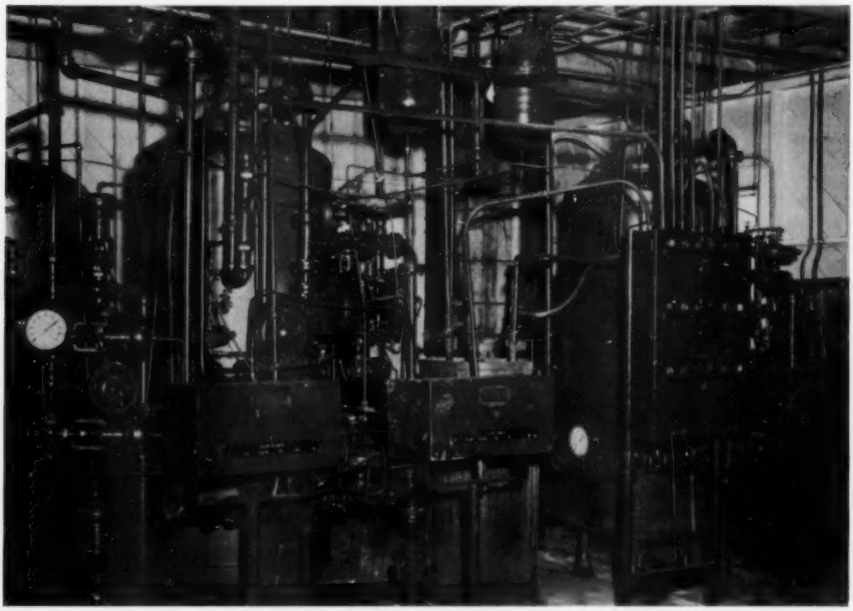


Fig. 2. Demineralization Equipment at Matagorda Island

Front view shows piping, valves, and control panel for automatic operation. Wood stave degasifier is visible in right background.

After the many difficulties previously experienced in producing a satisfactory drinking water supply for Matagorda Island, it was indeed a revelation to observe the flawless automatic operation of this plant. On the very first day of the plant's operation, scores of airmen

bearing canteens lined up near the plant for a drink of fresh water. The expression on their faces after they had the drink plainly indicated that the engineering effort that had gone into the design and construction of the plant had not been in vain. On an isolated island where summer temperatures sometimes exceed 105°F and recreational facilities are extremely limited, fresh potable water is of the utmost importance to the morale of the personnel.

Since the plant has been in operation one modification has been introduced—the use of liquid caustic in place of flake caustic soda. The liquid caustic is now dispensed from a tank by air pressure, a technique similar to that used for dispensing the sulfuric acid. This method has eliminated the potentially hazardous practice of letting unskilled airmen handle flake caustic soda.

During the months of February and March 1954, it became necessary to shut down the plant on several occasions because of lack of fresh-water storage facilities—the 150,000-gal clear-water storage tank had been filled to the brim. Such a situation could never, of course, have developed when the thermocompression distillation units were used. Now that an adequate potable-water supply system has been constructed and has been proved successful, provisions are being made to pump drinking water to all barracks and administrative buildings. The airmen need no longer walk the great distance to the consolidated mess hall for a drink of water.

In the final analysis, it has been determined that for each 1,000 gal of finished water, a total of 71 lb of sulfuric acid, 14.6 lb of common salt and 15.7 lb of caustic soda are required. On the basis of the prevailing rates for these materials (delivered to the island), each 1,000 gal of treated water costs $2.04. Through a recent modification, which allows a portion of raw water to be blended with the demineralized water, the unit cost has been reduced to approximately $1.80. This is still expensive, of course—but what substitute is there for a dependable potable-water supply?

Seven Years of High-Rate Filtration

John R. Baylis

A paper presented on Nov. 7, 1955, at the Florida Section Meeting, Orlando, Fla., by John R. Baylis, Engr. of Water Purif., Div. of Water Purif., Bureau of Water, Chicago, Ill.

A NUMBER of filters in the Chicago South District Filtration Plant are now in their eighth year of continuous operation at rates in excess of 2 gpm per square foot of filter surface. On Feb. 1, 1948, eight of the 80 filters then in operation were set at a rate of 4 gpm per square foot by adjustment of the filter rate controllers (Fig. 1). Nine months later, four of these eight were reset at a rate of 4.5 gpm, and two additional filters were set at 5 gpm, making a total of ten filters operating at high rates. The purpose of this paper is to present a summary of operational data for these filters for the 7-year period beginning in 1949. (Since neither the number of filters nor their rates remained constant during 1948, the data for that year are not included in this presentation.)

The experience with these filters through February 1950 has previously been described by the author (*1*). The paper included a number of tables comparing average monthly rates and two tables indicating the results of daily tests of turbidity and floc volume for the 5-gpm filters. The opinions and conclusions expressed in 1950 are as valid today as when written. Each additional year's experience provides added confirmation of the accuracy of the data. Since that time, monthly averages have been tabulated annually in the plant's publication, *Pure Water*. In the present summary, however, only yearly averages are supplied in most of the tables.

The time in which a filter can be maintained in service is important. This is especially true of high-rate filters, as they require more filter washes per day. The entire washing process —washing the filter and closing the backwash valve, opening the influent valve to allow the filter tank to fill with settled water, and opening the effluent valve—requires about 15 min (*see* Fig. 2). For average filter runs of 24-hr duration, the time out of service amounts to 1.04 per cent. This is not quite correct, however, for 15 min or longer may be required to drain the water above the sand bed almost to the level of the sand, as is customary practice. When the influent valve is closed, the water level will begin to decline. If the loss of head for a given filter is 8 ft, and the available loss of head is 10 ft, the filtration rate will start to decline as soon as there is no longer sufficient head to maintain it. At the end of the draining-down period the filtration rate may be less than half what it was at the time the influent valve was closed. The volume of water filtered during the draining-down period may be only three-fourths of that which would have been filtered if the rate did not decrease. At a rate of 5 gpm, this is the equivalent of a loss of 3.75 min. As it would require

considerable time to take this loss into account, it was not done. The time a filter is out of service, as indicated in Table 1, is based entirely upon the filter operator's record, which shows the time the effluent valve was closed and the time it was reopened, but does not account for the reduced rate. The time the filter is in service would be about 0.5 per cent less than the figure given in the table. Thus, the effective time in service, instead of averaging 98.9 per cent for filters operated at 2 gpm, as indicated in Table 1, would be close to 98.4 per cent.

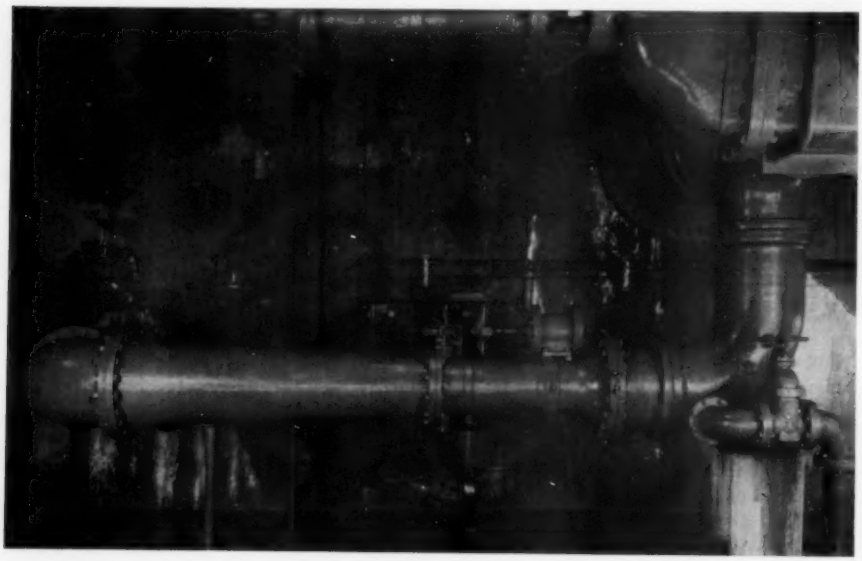


Fig. 1. Filter Rate Controller

The chief difference between the filter rate controllers used in the Chicago South District Filtration Plant and those commonly used elsewhere in the long venturi section, designed to offer minimum interference with the even flow of water.

Length of Filter Run

Table 2 shows the annual average filter runs for the period 1949–54. The averages for the entire 5-year period do not vary so widely as the monthly averages for those years. Daily averages (as indicated by the maximum and minimum columns in Table 3) vary still more widely than the monthly figures. For the period shown (January 1953–October 1955), the runs have ranged from 4.7 hr for the day of shortest run to 57.2 hr for the days of longest run. Most of this disparity may be attributed to the daily variation in both number and kind of microorganisms present. A second factor, in this regard, is that one settling basin was out of service for much of the period November–April of each year, decreasing both mixing and settling time by a third during those periods. (It was necessary to remove a single settling basin from service each

year in order to change the raw-water meters from the venturi tube type to flowmeters.) It is not recommended, therefore, that the reader attempt to evaluate too closely any but the average-run data in Table 3.

Analyzing the figures in Table 2 more closely, it may be assumed that the amount of flocculated material going to a filter operating at 4 gpm is twice that of a filter operating at 2 gpm. The amount going to filters operated at 4.5 and 5 gpm would be proportionately greater. Assuming that the clogging rate is in proportion to the amount of flocculated matter going to the filters, one may estimate that filters operated at 4 gpm will have runs approximately half as long as those of the 2-gpm filter; that is, about 14.4 hr, as the runs on the 2-gpm filters averaged 28.7 hr. Following this logic, the runs for the 4.5- and 5.0-gpm filters would be 12.8 and 11.5 hr, respectively. These figures are not far from the runs actually recorded over the 6-year period.

TABLE 1

Time in Service

Year	2-gpm Rate*	4-gpm Rate (4 Filters)	4.5-gpm Rate (4 Filters)	5-gpm Rate (2 Filters)
	Time in Service—*per cent*			
1949		98.0	97.2	96.5
1950	99.0	98.0	97.8	97.0
1951	99.1	98.3	97.9	97.2
1952	99.0	97.8	97.7	96.0
1953	98.8	98.0	97.4	96.9
1954	98.6	97.5	97.5	96.9
Avg	98.9	97.9	97.6	96.7

* Four filters recorded for 1950–52; two for 1953–54; none for 1949.

This simple comparison of the actual and computed filter runs does not take into account all of the facts. Filters were washed after 2 days of operation, regardless of loss of head. There were periods of short duration in which the 48-hr limit determined the time to wash. If the filters had been allowed to continue in service at all times until the loss of head reached 8 ft, the average length of filter run for the 2-gpm filters would have been slightly higher, probably close to 30 hr instead of 28.7 hr. This would bring the computed estimates nearer to the actual lengths of the runs recorded for the 4- and 4.5-gpm filters.

TABLE 2

Length of Filter Run

Year	2-gpm Rate	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Length of Run—*hr*			
1949		15.2	12.4	9.9
1950	33.0	17.1	14.7	11.3
1951	36.6	19.6	16.6	12.9
1952	26.1	16.5	14.5	10.8
1953	26.3	12.6	11.3	8.4
1954	21.3	11.6	9.9	8.3
Avg	28.7	15.4	13.5	10.2

In considering the data for the 5-gpm filters, it must be taken into account that an 8-ft loss of head could not ordinarily be obtained; generally, these filters had to be washed under conditions of 7–8 ft of head loss. Had it been possible to obtain the same loss of head as for the other filters, the average length of filter run for the 5-gpm filters would have been more than the recorded 10.2 hr, probably between 11 and 12 hr.

Another factor must also be considered: the initial loss of head is greater

on a high-rate filter than on filters operated at 2 gpm. More precisely, a 5-gpm filter has an initial loss of head about twice that of a 2-gpm filter. At a temperature of 45°F the filters in the South District plant have an initial head loss of approximately 0.6 ft at the 2-gpm rate, and 1.3 ft at the 5-gpm rate. Running the filters to 8-ft loss of head, the lower-rate filter would have an increase over the initial head loss of about 7.4 ft, while the 5-gpm filter would have only 6.7 ft of increase. These factors are mentioned so that allowance may be made for their influence in using the data presented. The loss of head in the rate controller and the filter effluent piping is not great at the 2-gpm rate, yet it becomes considerable at the 4- to 5-gpm rates.

Turbidity and Floc Volume

Because of the work involved, daily turbidity tests were not made on the effluents of all of the high-rate filters—only the 5-gpm filters were sampled. Annual summaries for the 6-year period are given in Table 4. The yearly averages are low, as were the monthly averages used in computing them. During the 6-year period, the laboratory recorded two tests which could be considered objectionable. One of these showed a turbidity of 1.3 ppm on the effluent of Filter 77 in August 1954; the other was a reading of 2.0 ppm on the effluent of Filter 10 in September 1954. In both instances, a note was made on the record sheet that the turbidity was composed of colloidal rather than flocculated material. An insufficient application of the coagulat-

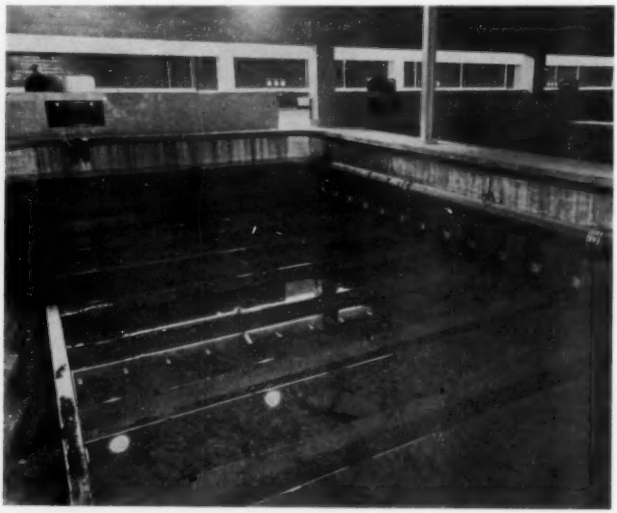


Fig. 2. Backwashing a Filter, South District Plant

The sediment is just beginning to overflow the wash water troughs. Each filter has nine troughs spaced 6 ft apart, center to center.

TABLE 3

Filter Runs for Years 1953–55
Average of All Filters

Month	1953			1954			1955*		
	Length of Run—*hr*								
	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.
Jan.	20.0	47.8	10.3	21.4	37.5	14.9	14.0	37.5	8.8
Feb.	36.6	53.1	25.7	27.0	45.4	12.9	19.2	32.2	11.4
Mar.	27.1	57.2†	18.0	24.5	42.3	14.5	13.5	33.6	8.9
Apr.	16.0	25.4	8.2	12.3	40.6	7.0	16.8	23.2	12.4
May	20.6	43.8	12.7	12.8	24.1	7.0	12.0	21.9	8.7
Jun.	11.9	19.3	4.7‡	10.0	35.3	5.3	13.0	28.4	8.5
Jul.	9.9	24.6	6.0	13.3	28.9	5.1‡	16.5	45.5	6.5‡
Aug.	23.5	35.6	8.9	29.5	46.6†	16.1	29.5	49.0†	15.9
Sep.	25.1	41.8	14.3	23.2	33.5	16.3	27.4	49.0†	18.3
Oct.	15.2	35.8	9.2	17.4	27.2	10.1			
Nov.	13.5	19.9	10.4	10.3	18.6	7.4			
Dec.	19.3	39.5	8.1	11.3	20.0	6.9			
Avg	19.9			17.7			17.9*		

* January–September only.
† High for the year.
‡ Low for the year.

ing chemical could have been the cause. No further investigation of the tests was made and there was later no means of checking back to determine the cause. Colloidal turbidity does not ordinarily occur on one filter alone. The outlet water from the plant, tested every 4–6 hr, showed zero turbidity each day of the month for the 2 months in which the two high readings were recorded.

Floc, or coagulated material, is often measured by turbidity tests. A more accurate test, however, is to measure the volume of the floc itself. Where there is considerable floc, this may be done with a centrifuge. When the amount is low, the test is made by comparison with standards of known floc volume. Procedures for preparing floc standards and making tests have been described in detail by the author (*2*).

The unit "floc volume" is based on the volume of flocculated material in the water: thus, 1 gal of floc in 1 mil gal of water is 1 floc volume. The floc volume is a figure generally about 15 times the turbidity. A water containing 1.0 ppm of flocculated material will have a floc volume close to 15. The relationship, however, is influenced by the turbidity of water before coagulation, and the figure given applies only to low-turbidity raw water (less than 50 ppm).

Table 5 compares the annual averages of the floc volume in the effluents of the 5-gpm filters. The table also gives the maximum day for each year of the 6-year period, as determined by a single daily test.

The maximum floc turbidity for a single test was 5.0, which would represent a turbidity of about 0.4 ppm. The average floc volume over the

6-year period is less than 0.1. This is quite low and indicates a high quality of water. Many filtration plants pass considerably more than this volume of floc in water which is considered to be of good quality.

Bacteria Counts

Table 6 gives the yearly average of coliform bacteria found in water from the high-rate filters. During April 1952, there were a few samples of water that had high coliform counts; these, however, were not confined to the high-rate filters. Investigation disclosed the cause to be in the sample bottles. Because these data tend to be misleading, two averages for 1952 are given: one including the high coliform counts indicated, and another without.

The water was prechlorinated throughout the period of the test. For 1950–52, the prechlorination dosage was enough to produce substantial residual passing through the filters, and good results were expected. Beginning in May 1953, the prechlorination dosage was lowered, so that the water passing the filters had only slight residual chlorine. Postchlorination, however, was increased, so that the water on leaving the plant would have the desired residual (0.6 ppm). The filters, of course, were sampled in advance of postchlorination.

The general averages of the filters show no major discrepancy between the counts for the high-rate filters as compared with those of the filters on variable rates of 2.3–4.7 gpm, or those operated at a 2-gpm rate. The general average of the coliform bacteria (after reduction of the prechlorination dosage) has been low, and shows the water from all filters to be of high quality with respect to bacterial content. Nevertheless, enough additional chlorine was added to produce a combined chlorine residual of 0.6 ppm in the water leaving the plant. There is no reason to fear that the water from the high-rate filters is less safe than that from the 2-gpm filters. If the entire Chicago water supply were filtered at 4–5 gpm, it would be just as safe as water filtered at 2 gpm.

TABLE 4

Yearly Average Turbidity for 5-gpm Filters

Year	Filter 10		Filter 77*	
	Turbidity—*ppm*			
	Avg	Max. Test	Avg	Max. Test
1949	0.01	0.50	0.05	0.58
1950	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00
1952	0.02	0.50	0.04	0.40
1953	0.00	0.00	0.00	0.10
1954	0.04	2.00	0.02	1.30
Avg	0.012		0.018	

* Results shown are composite of tests on Filters 77 and 80.

TABLE 5

Floc Volume for 5-gpm Filters

Year	Filter 10		Filter 77	
	Avg	Max. Day	Avg	Max. Day
1949	0.03	5.0	0.02	5.0
1950	0.00	trace	0.01	1.0
1951	0.00	0.0	0.00	0.0
1952	0.26	5.0	0.20	4.0
1953	0.07	0.2	0.08	0.3
1954	0.13	0.3	0.12	0.4
Avg	0.08		0.07	

Cotton Plug Filters

The most sensitive test yet devised for determining the amount of coagu-

lated material passing through filter beds is the cotton plug filter. A description of this filter was published by the author in 1949 (*3*). The cotton is placed inside a glass tube measuring 1 in. in ID and 2 in. in length (*see* Fig. 3). The cotton must be packed tightly enough to prevent the development of free-flowing channels, yet not so tightly as to interfere with the flow of water. One soon learns from experience the most satisfactory amount of cotton to use and how best to pack it into the tube. Absorbent cotton is difficult to dry to constant weight. The best procedure, therefore, is to burn the cotton with the material retained by it and determine the results on the basis of the comparative weight of ash. Unless the ash content is low, the weight of the cotton ash will not substantially affect the results. At Chicago, the cotton plugs are usually changed each week. Knowing the rate of flow through the filter (usually close to 100 ml per minute), and the time in service, the content of coagulated material (expressed as parts per million of ash) may be calculated. Results of the cotton plug filter tests are given in Table 7.

TABLE 6

Coliform Bacteria Counts

Year	Automatic Rate (2.3–4.7 gpm)	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Bacteria Count–*number/100 ml*			
1950	0.035	0.057	0.050	0.073
1951	0.011	0.007	0.012	0.001
1952	0.057	0.122	0.038	0.218
	0.017*	0.009*	0.011*	0.001*
1953	0.018	0.003	0.001	0.016
1954†	0.024	0.008	0.007	0.011
Avg	0.021*	0.017*	0.016*	0.022*

* Averages not including high count (caused by contaminated sample bottles) of April 1952.
† Count for 2-gpm filter for 1954 was 0.012.

The cotton plug filter is the only test that reveals any reduction in the quality of the water passed through the high-rate filters, samples of which show more ash than those from the 2-gpm filters. Though actually quite small, this increase must be taken into account in considering high-rate filtration. Use of the cotton plug filter will provide adequate warning if the coagulated material passing the filter is approaching the danger limit.

Little is known about the amount of coagulated material that passes through filter beds. That some coagulated material passes every filter bed handling coagulated water does not seem to be widely understood by filtration plant operators; or, if understood, it is considered to be of no significance. The author believes it better to record the amount of flocculated material passing through the filters, even though it is very small.

Good use of cotton plug filters was made in the Chicago Experimental Filtration Plant to compare filter efficiency. It has been 15 years since the first article describing the filter was published (*4*), yet so far little use has been made of this extremely sensitive device. This indicates a general lack of interest in the efficiency of filters in removing coagulated material from water so long as the filtered water is not noticeably turbid.

Cotton plug filters should be used on all of the filters in every filtration plant. They are the best means of keeping account of the efficiency of the filters. A word of caution, however: the results obtained in one plant may not be similar to those of another plant.

TABLE 7

Cotton Plug Filters

Year	Avg. of All Filters	2-gpm Rate	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Ash—*ppm*				
1949	0.047	0.045*	0.055	0.059	0.066
1950	0.037	0.028	0.048	0.045	0.060
1951	0.042	0.039	0.067	0.064	0.084
1952	0.077	0.039	0.058	0.084	0.084
1953	0.060	0.057	0.067	0.089	0.087
1954	0.058	0.056	0.073	0.090	0.082
Avg	0.054	0.044	0.059	0.072	0.077

* 3-gpm rate.

The filters in a given plant are tested on the basis of relative efficiency. If the performance of one filter is noticeably different from that of the others, then there must be a cause. Filtration plants have been observed in which considerable flocculated material was passing through the filters. The cotton plug filter would reveal this fact and would probably lead to remedial action. During periods of weak coagulation, a small amount of acid-treated sodium silicate is used to strengthen the coagulation at the South District plant. The use of silicate is not governed by the filtration rate, for only a few of the 80 filters operate at high rates. Rather, the need for silicate is determined by the character of the raw water. During periods of weak coagulation the coagulated material will readily pass through filter beds operated at 2 gpm, or even at lower rates of filtration.

Filter Performance

The measure of filter performance is the amount of water (in millions of gallons) passed through each filter per 1-ft increase in loss of head. The performance of the high-rate filters is compared with that of the 2-gpm filters in Table 8. Filters operated at a constant rate of 2 gpm had an average performance of 0.71 mil gal for the 6-year period, whereas filters operated at a rate of 4 gpm had an average performance of 1.02 mil gal, representing an increase in performance of 44 per cent over the 2-gpm rate. This performance has continued to increase

Fig. 3. Cotton Plug Filter

The filter is connected by copper tubing at upper left to 20-in. effluent line. Every particle of coagulated material in the water passing through is retained in the cotton and allowed to accumulate until visual inspection indicates that there is enough to be weighed after burning to ash in a muffle furnace.

each month throughout the 6-year period of the tests.

In the July 1950 article to which reference has previously been made (*1*), the seventh of a series of 20 questions frequently asked the author was: "Why is the filter performance greater for the high-rate filters than for the low-rate filters?" The answer given at that time was:

> This question cannot be answered definitely at present. In general, one would expect the filter performance to be the same regardless of rate or perhaps slightly less for the high rate. It may be, however, that the rapid flow of water into the filter causes deeper penetration of the coagulated material.

This still seems as precise an answer as may be given. One possible factor not previously mentioned is that loss of head often increases at an accelerated rate: for example, if the increase in loss of head in the first part of the filter run is 0.5 ft per hour, it may be as much as 0.6 ft or more per hour when the head loss is near 8 ft. For short filter runs (4–8 hr) the rate of clogging also increases more rapidly toward the end of the run. Starting with a higher initial loss of head on the high-rate filters, the total increase in head loss up to 8 ft is not as great as that produced by a low filtration rate. This very minor difference, however, would hardly account for the considerable increase in filter performance as the rate of filtration is increased. The assumption that the coagulated material is carried deeper into the filter bed still seems the more likely explanation.

During the first 4 years of filter operation there was a gradual decline in the number of filter washes, from 28,831 in 1948 to 23,202 in 1951. Since 1951, the number of washes has increased rapidly, with 44,382 filter washes recorded in 1954. Part of the increase in 1953, 1954, and 1955 can be attributed to the previously mentioned replacement of the raw-water meters. The chief cause has been variation in the number and kinds of microscopic organisms. In June 1954, there were 5,642 filter washes, while in August of the same year there were only 2,059. The average daily pumpage at the plant was 389 mil gal in June, compared with 361 mil gal in August. This difference in the volume of water filtered would account for only a few of the additional washes in June. The greater part of the difference was clearly caused by the variation in the number of microorganisms in the raw water—from an average of 1,130 in June to 283 in August.

A tabulation of hourly filtration rates for the 68 filters set on automatic rates has been made for eight peak days in June and July of 1954. These rates, which vary from a low of 1.2 gpm to a high of 3.5 gpm, averaged about 2.7 gpm per square foot for the days recorded. Total plant production for those days ranged from a low of 439.4 mil gal to a high of 478.4

TABLE 8

Filter Performance

Year	2-gpm Rate	4-gpm Rate	4.5-gpm Rate	5-gpm Rate
	Volume per 1-ft Loss of Head—*mil gal*			
1949	0.61	0.93	0.90	0.94
1950	0.76	1.12	1.16	1.27
1951	1.07	1.35	1.46	1.56
1952	0.65	1.07	1.16	1.11
1953	0.69	0.88	0.95	0.85
1954	0.50	0.78	0.81	0.85
Avg	0.71	1.02	1.07	1.10

mil gal, and averaged about 451.4 mil gal. Comparable data for 1955 show hourly peaks not exceeding those of 1954. Trial tests were made in 1955 in which the pumpage and filtration rates were raised to 640 mgd. Thus, the 68 automatic filters were operating at rates slightly in excess of 4 gpm per square foot. The objective of this test was to determine whether the plant could be operated at such a high rate. Present peak rates are only about 80 mgd below the tested maximum of 640 mgd.

Conclusions and Recommendations

If a filtration plant is designed on the basis of a rate of 3 gpm per square foot, some saving in construction cost will be made over a design based on a 2-gpm rate. The filter area will be two-thirds of that required when the customary rating of 2 gpm is used. The cost, however, will be somewhat more than 67 per cent, for the influent and effluent piping and conduit requirements will be the same as those of a 2-gpm rate. Other equipment used in conjunction with a filter (such as operating tables) also will be the same. The cost of the filters alone may be lessened as much as 25–30 per cent as a result of using the 3-gpm rate.

The saving in operation cost will be very little if any; however, the cost certainly should not be greater. The fact that there is greater filter performance indicates slightly fewer filter washes, but this does not necessarily imply a saving in operational cost: certain equipment, such as backwash valves, is adversely affected by too little use.

On Jan. 18, 1952, the entire South District plant was placed on a high-rate test by reducing the number of filters in operation. Operation of the plant was continued in this manner until Feb. 1, 1953. Of the 80 filters, 30 were cut off, alternating from one filter to another, so that no single filter would be out of service for more than a week at a time. During the summer months, when the load was high, it was necessary to turn on a few of the idle filters for short periods during the peak demand. When the demand rate for the operating filters increased to 4 gpm, the filters were watched closely so that a few of the idle filters could be cut back into service to maintain the load at no more than 4 gpm. As soon as the peak load was over in the evening, the number of filters in service was reduced to 50. The high-rate filters used in the previous tests were kept in service at the same fixed rates —that is, 4, 4.5, and 5 gpm.

The author wishes to make quite clear that he does not advocate indiscriminate use of the 3-gpm rate. Experience with such a rate, however, in plants throughout the country, indicates it may be used in many circumstances. The water should be well conditioned, and increased rates of filtration should not be accompanied by a reduction in mixing and settling times. Generally, this means that plants designed on the basis of 2 gpm should not be converted to the 3-gpm rate unless operation demonstrates that shorter periods of mixing and settling produce good conditioned water for the higher rate. This statement applies mainly to the gradual accommodation of plants now in operation to meet increased water use. In the design of most filtration plants provision is made for overloads of 25–50 per cent. A design based on the 3-gpm

rate should be capable of handling such an overload.

The author cannot too strongly insist on the importance of making liberal allowances in designs for overloads on the filters. If the designer chooses to call the rating 2 gpm, and designs on that basis, then he should provide for an overload of at least 100 per cent. The mixing and settling basins also should be designed with considerable excess capacity. As the load on the plant increases, the operator can tell when an extension is needed. It may be when the peak consumption produces a filtration rate of 2.5, 3, 3.5, or 4 gpm. The opinion, expressed by many, that filtration rates must be maintained at or near 2 gpm without exception is in contradiction to experience, and a deterrent to progress.

Summary

1. Water such as that of the Great Lakes may be filtered at rates of 5 gpm per square foot of filter surface without depreciation of quality, especially with reference to bacterial content.

2. Filters operated at a rate of 4 gpm may be maintained in service 97.9 per cent of the time, provided the filters are washed and returned to service with reasonable speed.

3. The length of filter run is almost inversely proportional to the filtration rate: that is, filters operated at 4 gpm will permit runs approximately one-half the length of those possible at a 2-gpm rate.

4. The turbidity of water filtered at rates of 4–5 gpm is not measurably greater than that of water filtered at a 2-gpm rate.

5. The floc turbidity, measured as floc volume, is not greater for the high-rate filters than for the low-rate filters, except at infrequent intervals of short duration. The evidence of decreased efficiency at such times is not strong.

6. The bacteria-removal efficiency of filters operated at 5 gpm is equal to that of filters operated at 2 gpm. Good reduction of coliform bacteria was observed for the high-rate filters even when there was very little residual chlorine in the filtered water and before postchlorination.

7. The amount of coagulated material passing through a filter bed is best measured by the cotton plug filter. Although a slight increase of coagulated material does pass through the high-rate filters, the amount is so small as to be of minor significance. The cotton plug filter is the only device revealing this difference, and should be installed on all filters in every filtration plant.

8. The filter performance (volume of water filtered per 1-ft increase in loss of head) is greater for the high-rate filters than for the 2-gpm filters.

9. The 80 filters of the South District Filtration Plant had 44,382 filter washes during 1954. Peak demand for water is now within 80 mgd of the 640-mgd maximum capacity of the plant, which was run on a high-rate test for a period of 1 year.

10. High-rate filters should be introduced only when there is evidence that such rates will not decrease plant efficiency.

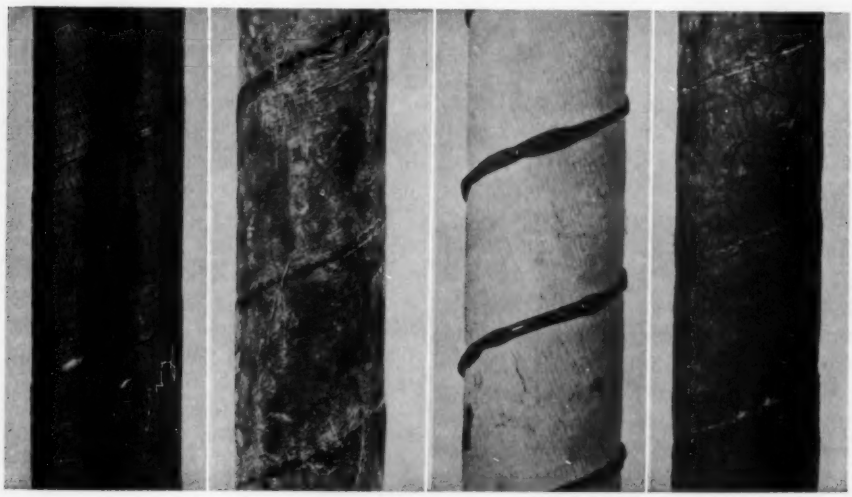
References

1. Baylis, John R. Experience With High-Rate Filtration. *Jour. AWWA*, 42:687 (Jul. 1950).
2. Baylis, John R. Sensitive Detection of

Suspended Matter and a Proposed Standard of Clarity in Filtered Water. *Jour. AWWA,* **11**:824 (Jul. 1924).
3. BAYLIS, JOHN R. Chicago South District Filtration Plant. *Jour. AWWA,* **41**:599 (Jul. 1949).
4. BAYLIS, JOHN R. Filter Operation and Maintenance. *J. NEWWA,* **54**:393 (Dec. 1940).

Correction

The paper "New Developments in Tests of Coatings and Wrappings" by Graydon E. Burnett and Paul W. Lewis (February 1956 JOURNAL, Vol. 48, pp. 100–120) contained several editorial errors. On p. 109, the top photograph in Fig. 7 was printed upside down. It is shown correctly below. Also, in Table 4, on p. 115, the air content percentage should have read "6" in the second column (instead of "none") and "16" in the third column (instead of "0.02").



(*a*) (*b*)

Fig. 7. Buried-Pipe Test Samples Before and After Exposure

The type of coating and the number of cycles to which the sample has been exposed are: (a) *microcrystalline wax with microcrystalline wax–impregnated laminated wrap, 25 cycles;* (b) *coal-tar enamel with crinkle kraft wrap, 25 cycles.* . . .

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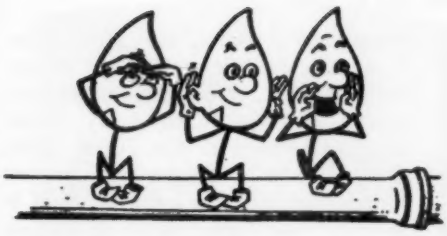

Percolation and Runoff

The Diamond Jubilation in St. Louis is now over, though, from where we sit, it has yet to begin. Which might be fortunate for us if it weren't so frustrating, for nothing so beggars description as inexistence. Actually, of course, we don't have to have been to what hasn't yet taken place to point out that this was the biggest and best birthday party that AWWA ever had. Not to overanachronize, however, we'll steer clear of such details as the record-breaking registration of 2,637 and merely report that these are the officers and directors who were inaugurated at the end of the Jubileeery to help lead the Association into the last quarter of its first century:

President—Paul Weir, general manager, Atlanta Water Works. Born in 1906, he holds a degree in civil engineering from the Georgia Institute of Technology (1928) and is a registered professional engineer in Georgia. His quarter century of service with the Atlanta water department includes 11 years as superintendent of the purification plant and 5 years as assistant general manager and engineer; he was named to his present post in 1947.

An AWWA member since 1929, he has been vice-chairman (1938), chairman (1939), and director (1943–46) of the Southeastern Section, which tendered him the Fuller Award in 1940. He was chairman of the Fuller Award Society in 1948 and is also a recipient of the Goodell Prize (1941). His activities within the Association have been unusually extensive: Prior to his distinguished service as vice-president in 1955–56, he served successively as trustee (1938–39), vice-chairman (1940), and chairman (1941) of the Water Purification Division and as secretary-treasurer (1949), vice-chairman (1950), and chairman (1951) of the Water Works Management Division, as well as having been a Water Resources Division trustee in 1948. His committee memberships have included Public Relations, Water Rates, Compensation of Water Works Personnel, Watershed Protection and Erosion Control, State Highway Legislation, Publication Review, Standards for Threads for Underground Service Line Fittings, National Committee for Utilities Radio, and Special Committee on Field Studies of Performance of Sulfur Jointing Compounds.

Other organizations in which he has been active are ASCE (past president, Georgia Section), the Georgia Engineering Society (past president), the Georgia Water and Sewage Assn.

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V.P.—Merryfield

Treasurer—Brush

(past president and secretary), the Natural Resources Div. of the US Chamber of Commerce (past director), the Atlanta Metropolitan Planning Commission, the Federal Civil Defense Administration (as a regional member of the Engineering Dept.), and the scholastic engineering fraternity, Chi Epsilon.

Vice-President—Fred Merryfield, professor of sanitary engineering, Oregon State College, and consulting engineer, Cornell, Howland, Hayes & Merryfield, Corvallis, Ore. Born in 1900, he received a B.S. degree from Oregon State College (1923) and an M.S. from the University of North Carolina (1930), and is a registered professional engineer in Oregon. He served as engineer with the Southern Pacific Railroad and US Army Corps of Engineers from 1923 to 1927. In 1927, he joined the faculty of Oregon State College as an instructor in the department of engineering, and served in that capacity until 1929, when he was appointed assistant engineer to the Dept. of Conservation and Natural Resources of North Carolina. In 1930, he returned to Oregon State College, where he served until 1942 as, successively, assistant and associate professor, engaged in teaching, research, and the design of water, sewage, and hydroelectric facilities. In 1943 he entered service as a staff officer and served with the Sixth Army in the Southwest Pacific area until 1944. Since 1945 he has served in his present capacity as professor and consultant in sanitary engineering at Oregon State College, and as a member of the Oregon State Water Resources Board.

An AWWA member since 1934, he has been secretary-treasurer (1936–43, and 1945–49) and director (1950–53) of the Pacific Northwest Section, which gave him its Fuller Award in 1944. He served successively as trustee (1950–52), secretary (1952–53), and chairman of the Water Resources Division. Committees on which he has been a member include Water Works Research Needs, Education, and the 1954 Convention Management Committee. In 1955 he served as chairman of the Harry E. Jordan Scholarship Award Committee.

Other organizations with which he is affiliated include ASCE, FSIWA, the Pacific Northwest Sewage & Industrial Wastes Assn. (past chairman), the American Society for Engineering Education, and the Willamette River Basin Committee. He is presently vice-chairman of the Region VII Education and Accreditation Committee of the Engineers' Council for Professional Development.

Treasurer—William W. Brush, editor of *Water Works Engineering*. Brush was born in Orange, N.J., in 1874 and was educated at New York University, from which he received B.S., C.E., and M.S. degrees. He served as engineer with the Brooklyn Water Dept., from 1894 to 1907, transferring to the New York Board of

(Continued on page 38 P&R)

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(Continued from page 36 P&R)

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Water Supply in the latter year. In 1910, he was shifted to the city's operating division, the Dept. of Water Supply, Gas, and Electricity, as deputy chief engineer of water supply. In 1927 he was appointed chief engineer of water supply, and served in that capacity until 1934, when he retired after a cumulative total with the three organizations of 40 years of service. He then accepted his present post as editor of *Water Works Engineering*.

His reelection as treasurer continues an unbroken record of 34 years of high office in the Association, for, except for a 2-year interval in 1928–29 when he was successively vice-president and president, Brush has been holding AWWA's purse-strings since 1922. In that time also he has been active on many committees, and has served ex officio as a member of both the Board of Directors and its Executive Committee. He received the John M. Diven Medal in 1932 and in 1937 was made an Honorary Member.

SECTION DIRECTORS

Alabama–Mississippi—Enoch M. Stickney, superintendent, Mobile Water Service System, Mobile, Ala. Born at Demopolis, Ala., in 1893, he studied civil engineering at the University of Alabama. In 1913–21 he worked on highway location and construction for the Alabama Highway Dept; in 1921–24 he served as assistant division engineer. In 1927 he was named assistant engineer for Mobile County, Ala., in which capacity he served until 1929. In 1930–36 he was vice-president of J. B. Converse & Co., consulting engineers of Mobile, Ala. In 1937, he returned to the Alabama Highway Dept. as division maintenance engineer, and served in that post until 1941, when he was appointed to his present position.

Arizona—Dario Travaini, superintendent, Div. of Water and Sewers, Phoenix, Ariz. A native of California, he was graduated from the University of California in 1924, and pursued graduate studies there in 1925. A registered professional engineer in Arizona and California, he has worked as a civil engineer for the Shell Oil Co., as a construction engineer for Standard Oil of California, as a sanitary engineer for the Sanitary District of Indianapolis, Ind., and as city engineer of Miami, Ariz. He has been associated with the city of Phoenix since 1931, and was appointed superintendent of the Water & Sewers Div. in 1950.

An active AWWA member, he has also served with distinction in a number of other organizations, including ASCE (past president, Arizona Section), the American Assn. of Engineers (past president, Phoenix Chapter), the Public Works Assn. (past vice-president, Arizona Section), the Arizona Sewage & Water Works Assn. (past president), and FSIWA (past Arizona director). He is a re-

(Continued on page 40 P&R)

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(*Continued from page 38 P&R*)

Ky.-Tenn.—Smith

Mich.—Barrett

cipient of the Fuller Award and of the Kenneth Allen Award for outstanding work in the field of sewerage.

Kentucky-Tennessee—Elmer Smith, general superintendent, Owensboro Municipal Utilities, Owensboro, Ky. Born at Brazil, Ind., in 1899, he was employed as a water works operator from 1919 until 1923, when he became maintenance engineer for the electric department of the Owensboro Municipal Utilities. In 1930 he was named chief engineer of the electric department, and served in that capacity until 1938, when he assumed his present position of general superintendent.

He joined AWWA in 1939 and served as chairman of the Kentucky-Tennessee Section in 1952–53. He is also a member of ASME.

Michigan—Edward D. Barrett, district sales manager, Chicago Bridge & Iron Co., Detroit. Born at La-Grange, Ill., in 1906, he received a B.S. degree from the University of Illinois in 1929. In the same year, he joined the Chicago Bridge & Iron Co. as a draftsman, and was soon engaged in construction and shop work. In 1930, he joined the firm's sales department, in which he now holds the position of district manager.

An AWWA member since 1944, he has served as trustee (1947), chairman (1952), and director (1955) of the Michigan Section, from which he received the Fuller Award in 1955. He is also associated with AWS, the Engineering Society of Detroit, the National Assn. of Corrosion Engineers, and the American Petroleum Institute.

Nebraska—Bert Gurney, partner, Bert Gurney & Assocs., manufacturers' representatives, Omaha. He was born in 1895 at Alta, Iowa. In 1924 he joined the consulting firm of H. H. Henningson in Omaha, and in 1925 he entered the field of sales. In 1952 he founded his present organization, which specializes in water and sewage treatment equipment.

A member of AWWA since 1935, he was elected chairman of the Nebraska Section in 1954. Since the organization of the Nebraska Section, he has been a member of the program committee, and in 1950–55 was chairman of the joint program committee for the Section and the Utilities Section of the Nebraska League of Municipalities, in which he has served as associate member officer since 1946. In 1956 he was tendered the Fuller Award.

Other organizations with which he is affiliated include FSIWA, the Ne-

Nebraska—Gurney

New England—Chase

(*Continued on page 42 P&R*)

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(Continued from page 40 P&R)

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braska Sewage & Industrial Wastes Assn., and the Omaha Engineers' Club.

New England—E. Sherman Chase, consulting engineer and partner, Metcalf & Eddy, Boston, Mass. Born at Merrimac, Mass., in 1884, he was graduated from the Massachusetts Institute of Technology in 1906, and is a licensed professional engineer in many states. In 1907 he served as a private assistant to Prof. L. P. Kinnicutt of the Worcester Polytechnic Institute. From 1908 to 1912 he was engaged as chemist, bacteriologist, and resident engineer at the Sewage Treatment Plant, Reading, Pa. He was associated with the Borough of Richmond, New York City, as an expert on sewage disposal in 1913, and with the New York State Dept. of Health, as assistant engineer, in 1920–27. He has been a partner in the firm of Metcalf & Eddy since 1927. His engagements as a consulting engineer have related to water supply, sewage disposal, and stream pollution problems throughout the United States, and he has given expert testimony in numerous stream pollution and water diversion cases.

He became an AWWA member in 1919 and served as trustee (1943) and director (1944–47) of the New England Section, which tendered him the Fuller Award in 1949. His AWWA committee memberships include Water Works Practice, National Water Policy, Compensation of Water Works Personnel, and Water and Sewage Works Development. In the past he has been an active member of the Executive Committee (1944–45), the Publication Review Committee (1947–52), and the Committee on Cross Connections (1931–49), and he collaborated in the revision of *Water Quality and Treatment*. His other organizational affiliations include FSIWA (past president), ASCE, NEWWA (past president and honorary member), APHA (fellow), American Institute of Consulting Engineers, the British Institution of Water Engineers, the Inter-American Assn. of Sanitary Engineers, the Boston Society of Civil Engineers, the New England Sewage Works Assn. (past president), and the sewage works associations of New York, New Jersey, and Pennsylvania. He attended the Third International Water Supply Congress in London as a general reporter, and is an honorary member of the professional fraternities, Chi Epsilon and Delta Omega.

New Jersey—Charles J. Alfke, executive vice-president, Hackensack Water Co., Weehawken, N.J. Born in 1892, he was a professional accountant (C.P.A.) prior to 1924, when he became comptroller of the Hackensack Water Co. and affiliated companies. In 1936 he was appointed manager and admitted to the board of directors of that company; in 1937, he was elected vice-president; and in 1941 he was named executive vice-president, in which capacity he serves the firm today.

(Continued on page 44 P&R)

MADRID, SPAIN . . . Diego DeLeon, 60

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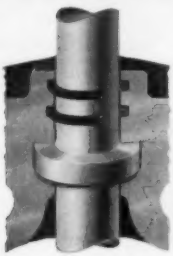

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KENNEDY Fig. 56
A.W.W.A. Standard Iron-Body Double-Disc Gate Valve, with Bell Ends.

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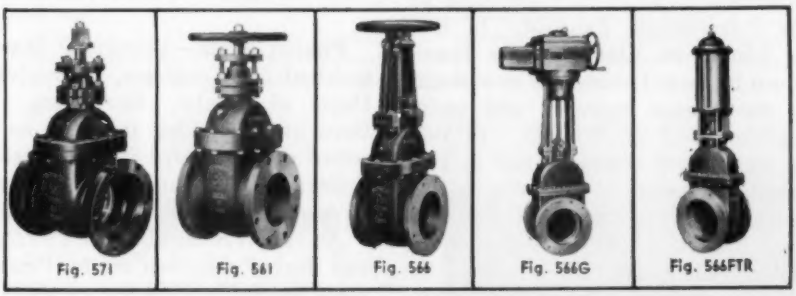

Fig. 571 | Fig. 561 | Fig. 566 | Fig. 566G | Fig. 566FTR

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(Continued from page 42 P&R)

Pacific Northwest —Allen

Pennsylvania— Matter

An active member of the New Jersey Section of AWWA for many years, he has served on the Committee on Water Works Administration, the Finance Committee, and the Administration Committee for the Employees' Pension System. He is also a member of the Joint Operation Board and president of the board of directors of the New Jersey Utilities Assn.

New York—John G. Copley, general manager, Elmira (N.Y.) Water Board. Born in 1907 at Lowman, N.Y., he received a B.S. in engineering from Princeton University in 1929, and is a licensed professional engineer in New York and Pennsylvania. In 1929–32 he was engaged in maintenance and construction engineering for the Pennsylvania Railroad. In 1932 he joined the Elmira Water Board, which he served until 1937 as assistant to the general manager and acting superintendent of filtration. In 1937 he was named secretary, and in 1942 general manager.

He served as trustee of the New York Section of AWWA in 1949–52 and as chairman in 1952. In 1947, the Section gave him the Fuller Award. Other professional organizations in which he has been active include the N.Y. State Society of Professional Engineers (past president, Steuben area chapter), and the Princeton Engineering Assn.

Pacific Northwest—E. Jerry Allen, assistant superintendent, Water Dept., Seattle, Wash. Born at Omaha, Neb., in 1900, he was educated at the University of Washington. He has served with the Seattle Water Dept. since 1934, as assistant chlorine operator (1934–38), assistant water control station engineer (1938–43), supervisor of purification and operations (1943–44), sanitary engineer (1944–49), and assistant superintendent (since 1949).

Joining AWWA in 1944, he has served as director (1951–53) and chairman (1954) of the Pacific Northwest Section. He is currently serving as a member of the Task Group on Watershed Protection and Erosion Control, the Water Distribution Division, and the special Committee on Revenue-producing Water. Other organizations of which he is a member are ASCE, APHA, the Engineers' Club of Seattle (past president), the State Civil Defense Water Supply Committee (chairman), and the Sanitary Engineering Advisory Committee of Washington State College.

Pennsylvania—Lawson D. Matter, assistant chief engineer, Pennsylvania Dept. of Health, Harrisburg, Pa. Born at Harrisburg in 1896, he received a B.S. degree from Gettysburg College in 1918 and is a registered professional engineer in Pennsylvania.

An AWWA member since 1923, he was elected chairman of the Pennsylvania Section in 1954 and received the Fuller Award in 1955. He has served as the vice-chairman of the Pennsylvania Civil Defense Organization for Public Water Works. Other organi-

(Continued on page 46 P&R)

New Cochrane SOLIDS-CONTACT REACTOR

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The relatively hard, turbid Rocky River supply for the city of Berea, Ohio, is quickly reduced in hardness to approximately 3.5 gr/gal and to a turbidity of less than 10 ppm by the Cochrane Solids-Contact Reactor shown above. An existing concrete basin 28′ square x 15′ deep was modernized by conversion to the Solids-Contact type. Using hydrated lime, soda ash and alum, the Reactor treats over 2,000,000 gpd at surprisingly low cost.

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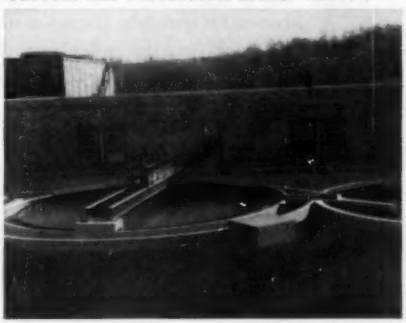

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(Continued from page 44 P&R)

Mfr.—Rankin

zations in which he has been active include ASCE, FSIWA, APHA, the Society of American Military Engineers, the Pennsylvania Water Works Operators' Assn. (past president), the Pennsylvania Sewage and Industrial Wastes Assn. (past president and secretary), and the Engineers' Club of Philadelphia.

Manufacturer—R. Steven Rankin, director, Sanitary Engineering Technical Div., Dorr-Oliver Inc., Stamford, Conn. Born at Henry, S.D., he received a degree in civil engineering from the University of Minnesota and is a registered professional engineer in Connecticut. He was employed by the Minneapolis (Minn.) Water Works Dept. from 1914 until 1916. In 1917 he joined the firm of Greeley & Hansen (then Pearse, Greeley & Hansen), which he served as draftsman, designer, and principal assistant engineer until 1926. Since 1927 he has been associated with Dorr-Oliver Inc. as sales engineer, assistant manager, and manager of the Sanitary Engineering Div. He has been director of the Technical Div. since 1955.

(Continued on page 48 P&R)

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(*Continued from page 46 P&R*)

He became an AWWA member in 1940. He has served as a member of the board of governors of the Water & Sewage Works Manufacturers Assn. (1945–47 and 1949–54) and the Harry E. Jordan Scholarship Fund Committee. He was elected president of WSWMA in 1954. He is also associated with ASCE, FSIWA, the Joint Committee for Advancement of Sanitary Engineering, the American Sanitary Engineering Intersociety Board (trustee and treasurer), and the New York and New England sewage and industrial wastes associations.

Industrial-waste disposal by biochemical processes will be the subject of a 2-week special summer program (Aug. 20–31) at MIT, under the direction of Rolf Eliassen, professor of sanitary engineering. The program will cover some of the fundamentals of microbiology and biochemistry; mathematical and analytical techniques employed in waste treatment and stream pollution studies; and design and operation of facilities. Professors Clair N. Sawyer and Ross E. McKinny will assist Dr. Eliassen. Details and application forms may be obtained from Summer Session Office, Room 7-103, Massachusetts Inst. of Technology, Cambridge 39.

Herbert K. Kingsbury has been appointed manager of product sales, centrifugal pump section, Allis-Chalmers Norwood Works. He has been with the company since 1943.

(*Continued on page 52 P&R*)

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pipe FOR MODERN WATER WORKS

(Continued from page 48 P&R)

W. H. H. Putnam, general manager of the Birmingham (Ala.) Water Works Board, has moved to Pittsburgh to take over his new duties as division manager for American Water Works Co.

Emory M. Ford, board chairman of Huron Portland Cement Co., Detroit, has been reelected chairman of the board of the Portland Cement Assn.

Clifford E. Earls has resigned as vice-president and technical advisor of White Star Sales Corp., Jacksonville, Fla., after 7 years. Mr. Earls was formerly superintendent of the St. Augustine, Fla., water treatment plant.

Louis F. Frazza, manager of direct sales, Transite Pipe Dept., Johns-Manville Sales Corp., New York, is shown taking the oath of office as the new director of the Water & Sewage Industry & Utilities Div., Business & Defense Services Administration, US Dept. of Commerce. Swearing him in is BDSA Administrator Charles F. Honeywell.

Leo V. Garrity, formerly assistant general superintendent, general manager, and chief engineer for the Detroit Water Board, and his former senior associate, L. W. Mosher, have entered private practice as Garrity & Mosher Engrs. at 14050 W. McNichols Rd., Detroit.

The USPHS has announced a number of appointments to the inactive-reserve component of its commissioned officer corps. The appointees, who will be available for service in emergencies and critical situations affecting the health of large groups of people, include the following AWWA members: William F. Cosulich, graduate student, Massachusetts Institute of Technology, Cambridge, Mass.; Broderick P. Haskell Jr., assistant engineer, Brown & Caldwell, Civil & Chemical Engrs., San Francisco; Charles R. Keatley, sanitary engineer, Research & Development Labs., US Army Corps of Engineers, Fort Belvoir, Va.; Harry C. Keyer Jr., chemical engineer, Louisville (Ky.) Water Co.; and Warren C. Westgarth, assistant professor of civil engineering, Oregon State College, Corvallis, and water plant supervisor, city of Corvallis.

Max Grossman, assistant superintendent and engineer, Atlantic City, N.J., Water Dept., has been reappointed to the State Water Policy and Supply Council.

William F. Neale has been made a partner in the firm of Whitman, Requardt & Assocs., Engrs., Baltimore. He has been with the organization for the past 12 years, except for a 3-year period as chief engineer of the Baltimore County Metropolitan Dist.

(Continued on page 94 P&R)

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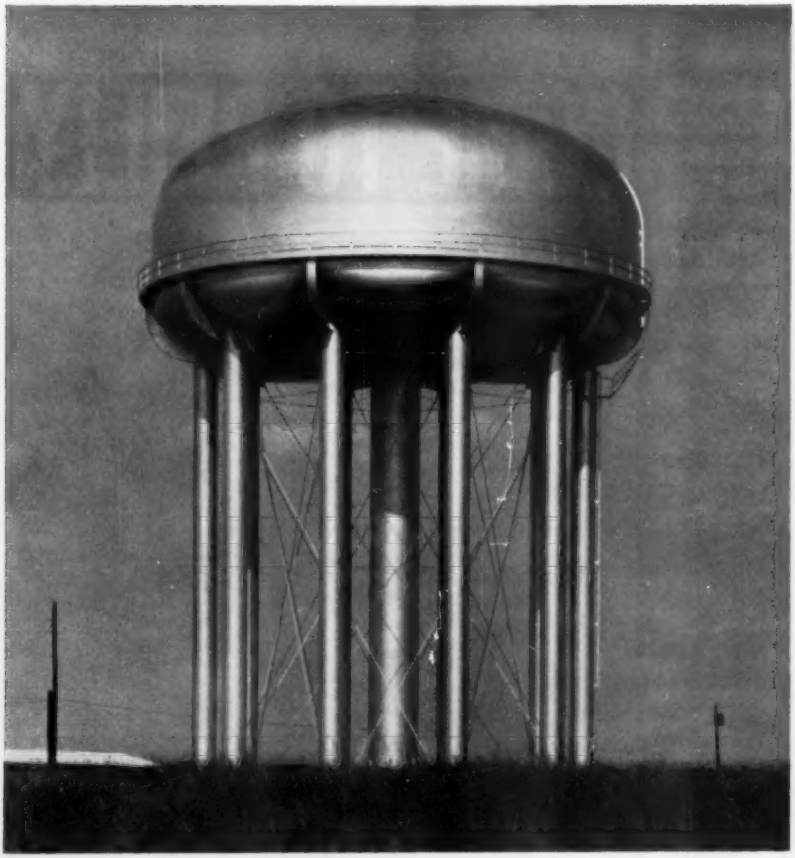

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

CORROSION

Of What Use Are Chemical Treatments in Controlling Corrosion. S. T. Powell & L. G. Von Lossberg. Mech. Eng., **77**:495 ('55). Experience has shown that when Na_2SO_3 is used for deoxygenation of boiler water, it is desirable to limit Na_2SO_3 concn. in boilers operating at 1,000 psi to 10 ppm (with pH 11) and for boilers operating at 1,200–2,000 psi to 5 ppm. When conditions are appropriate, less operating difficulties will be experienced from well controlled sulfite addn. to feedwater to be used for desuperheating than from addn. of chem. to boiler. Favorable experience with hydrazine treatment of boiler water is reported. Anhydrous hydrazine should not be considered for power station use, but when dild. to 35%, no greater care is required in handling than many other water-conditioning chems. Some persons are allergic to even dil. hydrazine solns. Control of condensate pH by addn. of NH_3 and amines is discussed. Volatile amines, especially morpholine, have been used successfully to maintain proper condensate pH. Use of waxy amines to form protective film over entire steam distr. and condensate-collecting system has given favorable results in low-pressure steam-generating systems. Limited amt. of trouble with boiler tube filming has been experienced with these and other org. internal chem. conditioners. In direct application of feedwater to superheated steam for desuperheating or attemperating, possibility must be considered of decompn. of amines in finely divided state in which they contact hot steam.—*CA*

Laboratory Studies on the Pitting of Aluminum in Aggressive Waters. T. E. Wright & H. P. Godard. Corrosion, **10**: 195 ('54). Studies have been made on pitting characteristics of Al when immersed in tap water of Kingston, Ont. Prelim. tests showed that pitting tendency of tap water was similar to that of raw water from Lake Ontario and, therefore, not dependent on treatment processes or contamn. from distr. system. On specimens immersed directly in lake, there was no pitting and lab. expts. showed that both no. of pits and depth of pitting decreased with increasing water veloc. Effects of various surface treatments were studied; in specimens etched with phosphoric acid, pitting commenced within few hr and was more extensive than in those merely treated with grease solvents. Resistance to pitting was not increased even when specimens which were treated with phosphoric acid were afterwards boiled in distd. water or allowed to dry in air. Exptl. results are given in tables.—*WPA*

Corrosion of Aluminum Alloys in Supply Waters. F. C. Porter & S. E. Hadden. J. Appl. Chem., Lond., **3**:385 ('53). Account is given of expts. on nodular pitting of Al alloys immersed in typical public water supplies. Pitting is characterized by formation of deep pits contg. acid liquid and covered with mounds of hydrated alumina. Tests were carried out in stagnant or slowly moving water. Most tap waters tested caused severe pitting; attack was most pronounced in hard waters. Most resistant wrought alloy was that contg. 1–25% Mn. Coating of 1% Zn alloy on Mn alloy prevented pitting of basis metal during 6-mo. test, but 25% of coating was dissolved. Of cast alloys, 1 contg. 5% Mn was slightly superior to 1 contg. 12% Si and 1 contg. Cu and Si. Surface finish had only slight effect on form and extent of corrosion. Pitting was decreased by raising temp. of water and above 50°C was almost absent, dark film being formed on surface of metal. Even at this temp., however, addn. of little Cu caused some pitting. For nodular pitting to occur, it was found that water must contain Ca bicarbonate, chlorides, Cu salts, and DO. As little as 0.02 ppm Cu caused severe attack and increasing concn. of Cu increased

(*Continued on page 66 P&R*)

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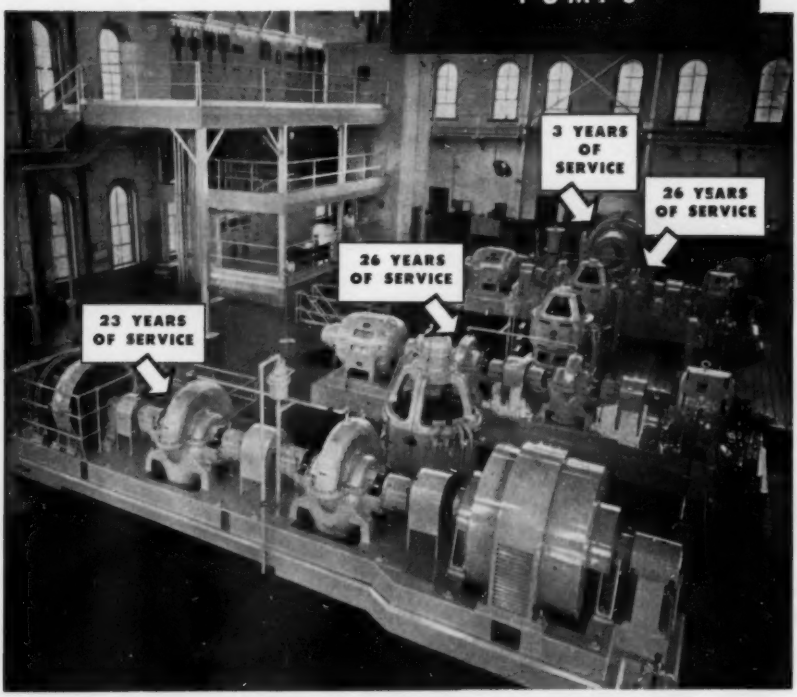

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(*Continued from page 62 P&R*)

amt. of corrosion in tests of up to 6 mo's. duration. In synthetic waters from which 1 or more of above constituents was missing, pitting, when it occurred, was not of nodular form. Theory of mechanism of this type of corrosion is outlined.—*WPA*

Cathodic Protection. M. CHALET. Tech. Eau (Belgium), **8**: No. 88, p. 11 ('54) and No. 89, p. 13 ('54). Cathodic protection of water mains in Brussels is described. Corrosion by stray currents from electric trams or trains or from faulty cables in d-c distr. systems is discussed. Cast-iron pipes, on account of their relatively high elect. resistance and numerous lead or rubber joints only suffer slow attack which is not localized but are subject to graphitosis. In modern reinforced-concrete pipes, joints are good conductors and electrolytic oxidation causes expansion of steel frameworks and cracking of surrounding concrete. Steel pipes, especially those with welded joints, offer no resistance to currents and are liable to intensive local corrosion. Protection by coatings and by introduction of insulating bands is discussed briefly. Cathodic protection may be employed by using distr. system as carrier for return of current from trams to negative line of the tramway substation, or by tapping current from available a-c network ('soutirage'). In latter case, current is reduced to very low tension by transformer, rectified and circulated through system to be protected to discharge system of old pipes, or, more cheaply, to nearby tramlines. Reactive anodes do not lower potential sufficiently to counteract stray currents. In distr. systems, steel piping is protected by 'soutirage.' Cast-iron piping is only protected near tramway substations or at junctions with steel pipes when negative potential of steel may cause corrosion of iron. Reinforced concrete piping is protected at danger points, by applying current to steel framework. Control is achieved by meters which record intensity of current at particular points in distr. system. Application of these methods to particular distr. systems in Brussels is described. —*WPA*

Remarkable Corrosion Phenomena in Sanitary Installations. KONTROLLSTELLE DER KORROSIONSKOMMISSION. Monatsbul. Schweiz. Ver. Ges- u. Wasserfach (Switz.), 33:304 ('53). Deposits of fine granular ma-

(*Continued on page 68 P&R*)

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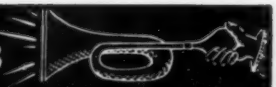

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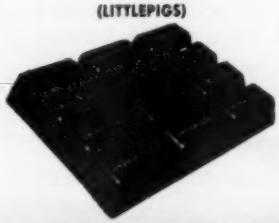

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(Continued from page 66 P&R)

terial, discoloration of baths and other fittings, and corrosion of pipes occurred in no. of dwellings. Cause was found to be use of bronze for certain fittings, such as pressure-reducing valves and cocks. Corrosion occurred both with soft and with hard water. In time protective coating formed with hard water but until completely formed could be washed off in pipes with vigorous flow of water. This was confirmed by expt. Remedy suggested is to ensure complete elec. insulation of metal used for fittings. Precautions necessary for earthing are described. Corrosive effects of stray currents within houses and from electric railways and trams are discussed.—*WPA*

Formation of a Protective Layer and Decomposition of Steam in Steel Tubes at High Temperatures. E. ULRICH. Brennstoff-Wärme-Kraft (Ger.), **7**:241 ('55). Occurrence of H in steam is due to decompn. of H_2O with formation of Fe oxides. H content of steam is thus measure of attack of steam on tubes. H concn. of steam decreases with time as result of diffusion of Fe ions through Fe oxide with consequent increase in thickness of hard, nonporous oxide layer. From Wagner's theory of scaling (*C.A.* **27**, 3388; **30**, 5165[8]), time dependence of H_2 concn. in steam is computed. H concn. in steam under const. service conditions is inversely proportional to square root of service period. It is possible from measurements of H concn. at two different times to compute H concn. in steam for any other moment. Ggeneral formula for ca'cn. of H concn. in steam boiler plants is given. —*CA*

Decreasing Cooling Water Corrosion. H. L. KAHLER & C. GEORGE. Petroleum Refiner, **24**:144 ('55). Corrosion of steel, Al, brass, and various other metals and alloys in water systems can be greatly reduced by supplementing dianodic treatment (addn. of $Na_5P_3O_{10}$ and Na_2CrO_4) with addn. of sol. Zn (0.8–10.0 ppm) or coating of Zn phosphate; latter does not cause loss in heat transfer. —*CA*

(Continued on page 70 P&R)

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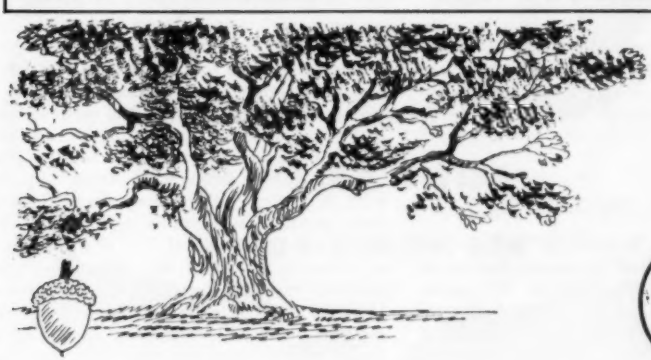

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(Continued from page 68 P&R)

Filming Amines. Use and Misuse in Power Plant Water-Steam Cycles. J. F. WILKES, W. L. DENMAN, & M. F. OBRECHT. Natl. Eng., **59**:20 ('55). Most effective filming amine corrosion inhibitors are satd. straight-chain primary aliphatic amines of 10 to 18 C atoms. Dosages are independent of dissolved-gas concn. They remove corrosion deposits. Pitfalls to be avoided are listed.--*CA*

AQUATIC ORGANISMS

The Influence of Hydrogen Sulfide and Ammonia on Animal Indicator Forms of the Saprobic System. H. A. STAMMER. Vom Wasser, **20**:34 ('53). After description of chem. characteristics of 4 classes of saprobic system, author describes investigation of effects, on indicator organisms of different classes, of H sulfide and ammonia. Expts. were designed to discover whether there was any connection between resistance of organisms to these substances and their position in saprobic system, whether threshold of toxicity of ammonia was low enough for this to be regarded as factor in distr. of organisms apart from different O requirements, and whether indicators of pold. water had greater resistance to H sulfide in absence of O than had unpold. water forms. Summary is given of relevant literature and methods used in investigation are described. 14 indicator forms, including insect larvae, annelids, turbellaria, and protozoa, were tested. In tests with H sulfide, all protozoa, regardless of their position in saprobic system, had low resistance in absence of O. With metazoa, on other hand, there was clear agreement between resistance and position in system. With 10 mg/l H sulfide, poly- and α-meso-saprobes resisted poison for 14 hr to 5½ days; β-meso-saprobes for 3–13 hr; and oligo-saprobes for 1½–6 hr. Effect of lower concns (3 mg/l) on poly- and α-meso-saprobes was similar to effect of removal of O, but these concns. were definitely poisonous to β-meso- and oligo-saprobes. There

(Continued on page 72 P&R)

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WATER FOR GENERATIONS TO COME

(Continued from page 70 P&R)

was clear relation between effect of ammonia and position of organisms. Toxic limit for polysaprobic organisms lay between 220 mg and 3.2 mg/l free ammonia; for α-meso-saprobes, between 4.3 mg and 0.3 mg/l; and for β-meso-saprobes and oligo-saprobes, between 0.4 mg and 0.08 mg/l. Probability of variations in this resistance at different stages of development of organisms is discussed. Results suggest that presence of poisonous products of decomposition would have same effect on organisms of unpold. water zone as reduction in concn. of O; O content would be decisive factor in slow-flowing or stagnant water, while poisons, especially ammonia, might be main influence in pold. but rapidly flowing and, therefore, O-rich water. 2 oligosaprobic insect larvae (*Perla* and *Ecdyonurus*) were exceptional in having considerable resistance to poisons tested. These larvae have been found relatively unaffected by alterations in chem. composition of water if sufficient O is present and are, thus, indicators of presence of high concn. of O but not of purity of water.—*IVPA*

Stream Pollution. Plankton and Industrial Pollution in Cleveland Harbor. C. C. Davis. Sew. Ind. Wastes, 27:835 (Jul. '55). 9 stations in Cleveland Harbor area of Lake Erie were visited every 2 wk during yr, Sep. 1950 through Sep. 1951. Quant. plankton samples were obtained from surface and from 6.5-m depth at each station. In Cleveland Harbor area, major portion of industrial effluents, and important vol. of domestic effluents, enter Lake Erie through Cuyahoga R. Quant. of plankton was uniformly small at those stations where poln. (as indicated by Fe content) was greatest, but apparently this was associated with lower productivity of river, rather than directly with poln. Small plankton quants. were also encountered in unpold. water. Therefore, it is thought that standing crop of plankton is not reliable index of poln. in localities such as that under investigation. Some common plankton species were lacking, or were rare, in most highly pold. water. Other forms (mostly tychopelagic) that were common at pold. stations were rare or

(Continued on page 74 P&R)

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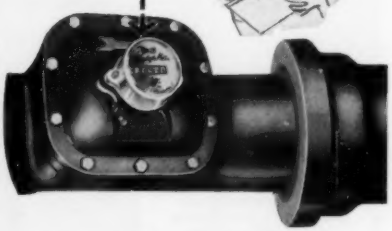
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(Continued from page 72 P&R)

lacking elsewhere. Again, however, it is probable that these phenomena were result of river conditions and not result of poln. Therefore, in locations such as Cleveland Harbor area, presence or absence of particular plankton species is not reliable index of poln. Examples are given of species of phytoplankton and zooplankton which occurred more frequently in dead or moribund condition at more highly pold. stations than elsewhere. Those are considered to be indicators of poln. Other means are more sensitive detectors, however, and more easily applied. That harmful effects of effluents is important is shown by death of plankters, and it is proposed to investigate these effects more closely.—*PHEA*

Aquatic Organisms as an Aid in Solving Waste Disposal Problems. R. PATRICK. Sew. Ind. Wastes, **25**:210 ('53). Studies of biol. microörganisms in stream bottom give reliable indication of effect of pollution on stream. Various tests using algae, insects, snails, and fish are described which det. toxicity of waste or polluted water. Practical applications of tests are discussed.—*CA*

The Effect of Phenols on Microorganisms in the River Pleisse. W. D. BEER. Wasserwirtsch.-Tech. (Ger.), **4**:125 ('54). Pleisse surveyed from Leipzig to Elster for 10 mo. to include periods of low, normal, and high flow. With no DO and 20 ppm steam-volatile phenols, no life existed. When increased flow raised DO to 5.3 ppm and decreased phenols to 4.3 ppm, first protozoal and algal species appeared and increased in variety and quant. as phenols were reduced to 0.2 ppm. All life disappeared when new poln. increased phenols to 18 ppm. Increase from 0 to 2.0 ppm phenols generally decreased variety and quant. of protozoa with no relation to the saprophytic classification. According to lab. tests, river protozoa tolerated phenolic compds. up to following approx. concns.: phenols and cresols 300 ppm, pyrocatechol 150 ppm, resorcinol 600 ppm, phloroglucinol 650 ppm, pyrogallol 33 ppm, hydroquinone 6.0 ppm, phenol waste conc. 13 ppm, of which 6.4% was hydroquinone and 11.4% higher unknown phenols.

(Continued on page 76 P&R)

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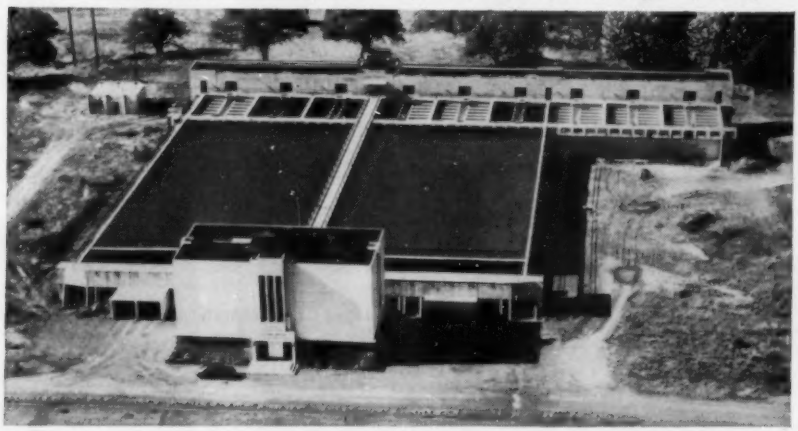

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(Continued from page 74 P&R)

Increasing temps. increased toxicity. pH up to 8.0 was tolerated, but NH_3 was toxic at pH above 6.5. Org. and mineral media studies indicated that protozoa do not utilize phenols directly, but that their quant. is dependent on that of phenol-metabolizing bacteria, which are primarily aerobic.—*CA*

The Importance of Algae to Water Works Engineers. J. W. G. LUND. J. Inst. Water Engrs., **8**:497 ('54). Freshwater Biol. Assn. noted that richness in algae reservoir or lake could generally be related to surface geology of catchment area and its land utilization. While there seems to be relation between P, N, and other nutrients in water to growth of algae, it is not absolutely certain what is cause of their growth. Algal growths may be controlled by use of Cu sulfate and Cl compds., but secondary results may be quite as unpleasant as primary trouble cured.—*CA*

LABORATORY METHODS

The Role of Solubility in Predetermining the Chemical Composition of Natural Waters. M. G. VALYASHKO. Doklady Akad. Nauk S.S.S.R. (Russ.), **99**:581 ('54). Data found in literature on concn. of various ions in natural waters were plotted, with ion concn. against total mineralization of waters. From shapes of curves obtained, following conclusions were reached: (1) mineralization is increased gradually by formation of more sol. compds. of principal ions; (2) mineralization of water is product of changes in sweet water with time, stability of different ions being variable, with result that their role in detg. salt compn. in water is also variable. Stability of anions in soln. increases in order P, Si, C, S, Cl, and of cations—K, Mg, Na, Ca. For variety of reasons, K is least stable, while Na and Ca compete for position of most stable ions.—*CA*

Rapid Determination of Water Hardness With Complexon. O. DESCHLER. Textil-Praxis (Ger.), **9**:183 ('54). Method described is simple, exact, and rapid. Water is titrated with soln. of complexon (I), 1 ml of 0.1*M* soln. of which contains 37.21 mg and is equiv. to 5.608 mg CaO or 4.032 mg MgO. With waters of lower hardness,

(Continued on page 78 P&R)

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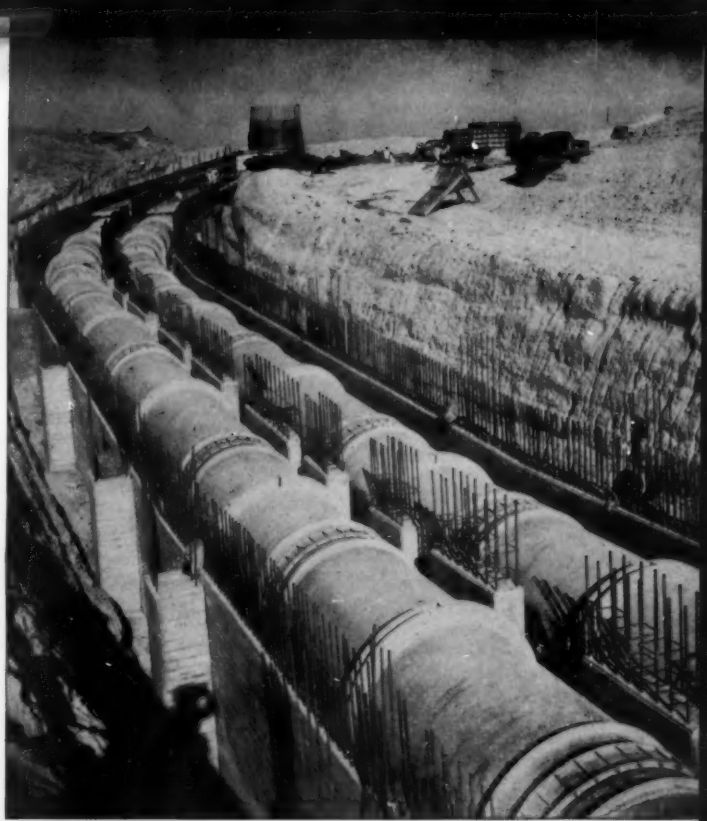

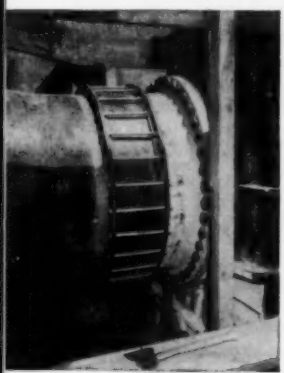

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(Continued from page 76 P&R)

standard soln. made by dilg. 1 vol. of 0.1*M* soln. to 5.6 vols. is more convenient. 100-ml sample is made to pH 10, and after addn. of Eriochrome Black T (C. I. 203) as indicator, is titrated to blue end point, this showing CaO plus MgO or total hardness. Another portion is then titrated at pH 12 with murexide as indicator to obtain CaO only. pH 12 adjustment is made by addn. of 10 ml of 5% NaOH. Buffer soln. for pH 10 may be made from 54 g NH_4Cl, 350 ml 25% NH_3 soln., 0.44 g $ZnSO_4 \cdot 7H_2O$, an amt. of **I** equiv. to Zn, and water to make 1 l. End point of total-hardness titration is more sensitive in presence of Zn ion. It is not sharp with Ca alone, but all hard waters also contain Mg, the latter reacting after Ca to give satisfactory end point. Fe, Mn, Zn, and Cu ions react quantitatively with **I** soln., and it can be used for detn. of these metals. Prepn. of pure **I** for analytical uses from com. products is described. Eriochrome Black indicator dye can be used in admixture with methyl red; this mixt. is offered in convenient tablet form by Merck.—*CA*

Photocolorimetric Determination of the Content of Arsenic and Phosphorus in Industrial Waste Liquors from Metallurgical Plants. L. N. KUSHAKOVSKII & T. D. POZDNYAKOVA. Gigiena i Sanit. (Russ.), No. 4:46 ('55). Aliquot of sample is analyzed for P by phosphomolybdate method by using aminonaphtholsulfonic acid as reducing agent; another aliquot is analyzed for sum of As and P by using fresh $SnCl_2$ as reducing agent. Results are accurate within 10–15% at concn. of 0.01–0.03 mg/l.—*CA*

Practical Application of Ultraviolet Radiation in Purification of Naturally Contaminated Water. H. C. RICKS ET AL. Am. J. Pub. Health, **45**:1275 ('55). Purification of contaminated water on individual consumer basis should not replace sound public health measures established to provide public with safe water. Also, it should not be considered as replacement for efforts to improve individual sources of water. Purifier studied and discussed, known as A.R.F. U-V Water Purifier, compensates for factors known to decrease bactericidal effect of ultraviolet radiation. Purifier constitutes an effective and safe means of purification of even heavily contaminated water providing (1) 2-minute warm-up period is observed prior to use of purifier; (2) water to be purified is reasonably clear by visual inspection (very muddy water, full of visible debris decreases efficiency of app.); and (3) lamp is changed, preferably every 6 months (based on 14-hr burning time daily).—*CA*

A Qualitative Measurement of Water Purity. H. RAHM. Mitt. Ver. Grosskesselbesitzer (Ger.), **32**:364 ('54). Purity of water is detd. by relative amt. of suspended matter. Definite vol. of water (for example, 50l), varying with its purity, is filtered through filter paper 40 mm in diam. supported by fine screen, under pressure of 0.4 atm. Ratio of time required for flow of first 10 l. to time for last 10 l. is "purity no." Tests throughout yr on river water showed that purity no. was roughly parallel to hardness, increasing with increasing hardness and falling with decreasing hardness (owing to pptn. increasing amt. of suspended matter and decreasing hardness). This test was also used to follow changes of water in clarifying basin (after addn. of $Al_2(SO_4)_3$). Same test was found of value in controlling filter operation and washing and in base exchanger water softening. In 1 instance, poor qual. of water after exchanger regeneration was found due to particles of resin. It was also found that qual. of water from exchanger was markedly poorer after exchanger had been shut down for 1 day or more. Method has also proved useful in controlling chlorination of water from spring. —*CA*

BOILERS AND FEEDWATER

Hydrazine for Boiler-Feedwater Treatment. R. S. HARSHMAN & E. R. WOODWARD. Trans. Am. Soc. Mech. Engrs., **77**: 869 ('55). Phys. and chem. properties of hydrazine are discussed, particularly as they relate to its use for scavenging DO in boiler feedwater. Amt. of hydrazine to use, methods of application, and methods of control of dosage are described. Several central power stations in United States are successfully using hydrazine in boilers operating from 400 to 2,500 psi, and others are preparing to use it. Hydrazine can reduce corrosion caused by DO without undesirable effects on boiler operation. Maintenance of hydrazine residual in water protects boiler against oc-

(Continued on page 80 P&R)

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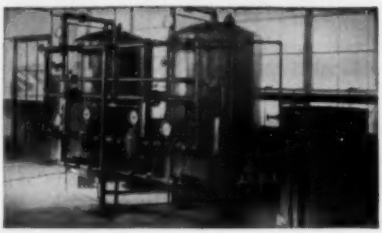

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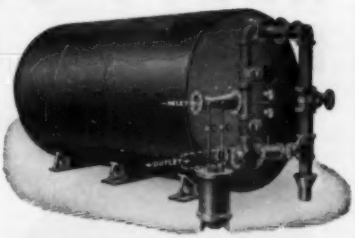

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(Continued from page 78 P&R)

casional increases in DO content, which occur with variations in operating conditions. Hydrazine does not interfere with normal control of pH of boiler water. It is easy to apply, and satisfactory methods have been developed for control of amt. required. When handling precautions (which have been outlined) are followed, hydrazine can be used without toxic effects. When rules were violated, only dermatitis and cases of eye irritation were noted. Amt. of hydrazine residual that can be maintained varies with individual boiler.—*CA*

Evaporators Use Blowdown and Treatments to Reduce Makeup and Silica. W. C. THOMPSON. Power Eng., **57**:58 ('55). Si control is explained. $MgCl_2$ and NaOH with Na aluminate were used to absorb and ppt. SiO_2. It was found that better results followed blowing evaporator instead of blowing down boilers. Details and methods of operation and results are given.—*CA*

The Effect of Rate of Flow on the Precipitation of Hardness-producing Salts, and Corrosion in Hot-Water Heaters. L. W. HAASE. Werkstoffe u. Korrosion (Ger.), **6**:81 ('55). Pptn. of salts causing hardness of waters by metal soln. is dependent on alky. of wall. Height of alky. is set by compn. of water and by amt. of depolarizing agent available per unit time, as well as by diffusion velocity. It is shown how to eliminate disadvantageous factors by suitable construction, without lowering efficiency of heaters.—*CA*

What's New in Demineralizing? D. MILLER. Power, **99**:73 ('55). 2-bed and mixed-bed demineralizing systems are explained, and advantages of arrangement described. Silica removal, degasification, end control, and regeneration for efficiency and economy are discussed.—*CA*

(Continued on page 82 P&R)

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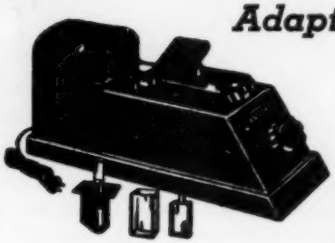

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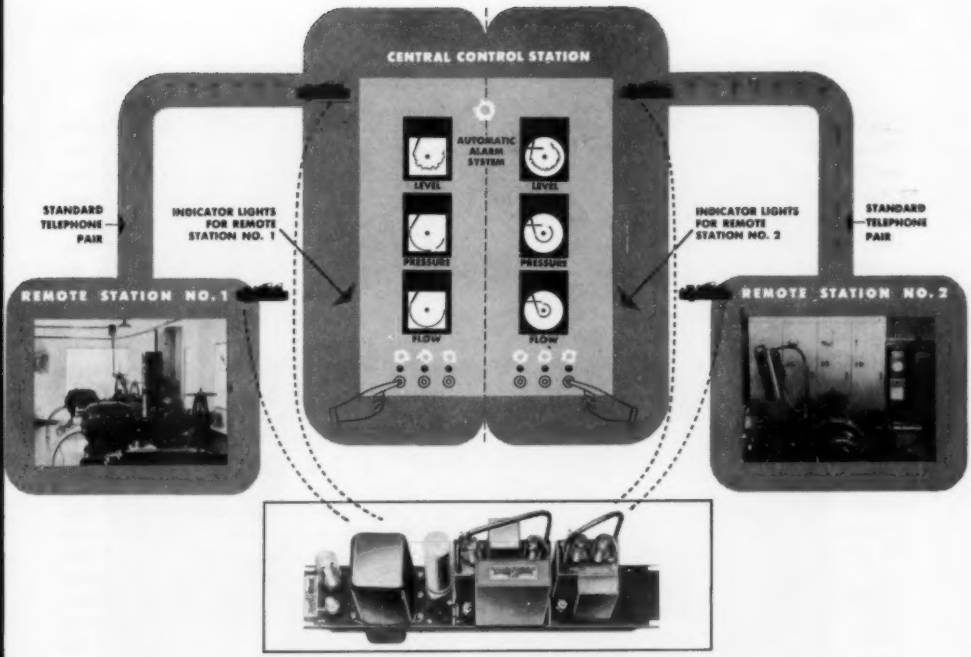

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(Continued from page 80 P&R)

Chemical Cleaning of Boilers—Use of the "Breathing" Method at the Gustav Knepper Power Plant. O. SMIDT. Mitt. Ver. Grosskesselbesitzer (Ger.), **28**:90 ('54). Boiler rated at 145 metric tons/hr, at 80 atm. and 500°, was finished 7 years after construction was started, so considerable rust had formed in tubes (largely 70 mm in diam. with 5-mm walls). Boiler was first treated with soln. contg. 3500 kg Na_3PO_4 for 34 hr and then with soln. contg. 12 metric tons of 30% HCl and 100 kg Hivolin inhibitor in about 70 cu m of water. Temp. of soln. in boiler ranged from 13.7 to 18.5°, and time of treatment was 30 hr. Acid was drained, filled with water contg. 4 tons Na_3PO_4, and washed out repeatedly with water. Amount of rust and sludge removed was 25 kg. After 72 hr operation, boiler had to be opened again and about 20 kg of rust and sludge removed. Second similar boiler was filled with soln. contg. 100 kg Na_3PO_4 and 200 kg NaOH. This boiler was heated to 80 atm. pressure and steam blown off at rate of 70–75 metric tons per hr; process was repeated 3 times. About 40 kg of rust and sludge was recovered. Results were comparable with those of acid treatment.—*CA*

Alkalizing the Water-Steam Cycle in Condenser-Type Boilers. H. E. HÖMIG & H. RICHTER. Mitt. Ver. Grosskesselbesitzer (Ger.), **36**:615 ('55). Purpose of current practice of alkalizing steam-water cycle in condenser-type power plants to about pH 9 is to suppress soly. of Fe in water. Fe dissolves in neutral water, even in absence of O, and in presence of CO_2 and consequent lowered pH, the soly. is increased tremendously. Fe oxides are deposited in various sections of system unless Fe soly. is repressed. Suitability of NH_3, cyclohexylamine, and morpholine was investigated, and latter found technically superior because of its phys. properties. Is uneconomical, though, unless make-up water is minimized and system contains only traces of CO_2.—*CA*

Removal of Silica in the Boiler Water. Test of Basic Magnesium Compounds as the Silica-removing Agent for Locomotive Boiler. M. AKAHANE & A. KUROSAWA. J. Chem. Soc. Japan, **58**:402 ('55). 6-month test was carried out to det. effect of basic Mg carbonate (I), MgO (prepg. by ignition of I), or Na aluminate added to boiler water on removal of SiO_2 in boiler water and of deposits. Use of any agents in approx. equal amt. to sum of SiO_2 and MgO contained in boiler water decreases SiO_2 by ½–⅓ ratio and makes deposits little and fragile.—*CA*

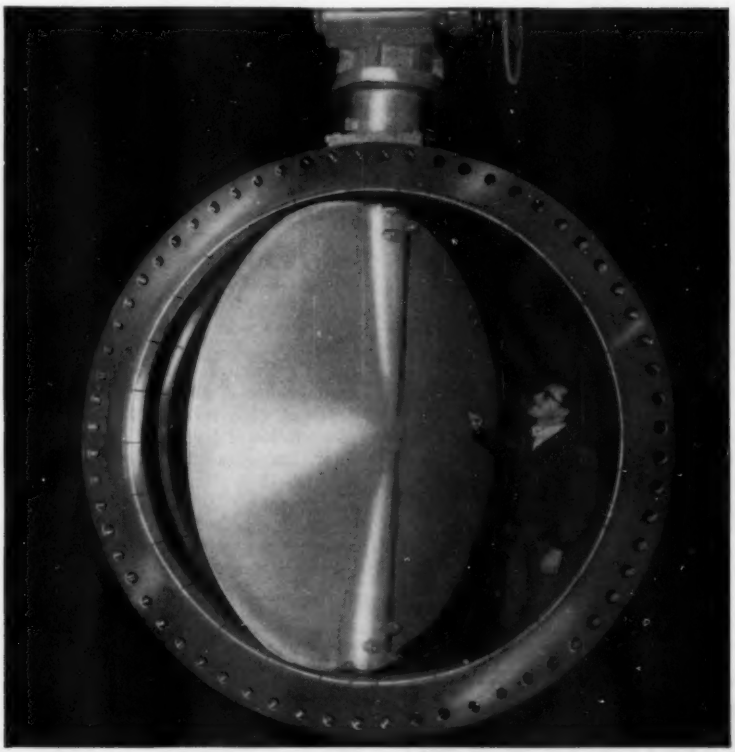
Boiler Feedwater Studies. I. Volumetric Determination of Aqueous Iodine Solutions Over a Range of Concentrations From 10^{-5} to 10^{-7} Normal. J. C. O'C. YOUNG. J. Imp. Coll. Chem. Eng. Soc., 8:94 ('54). Amperometric method for detection of end point of titration of aq. I soln. with $Na_2S_2O_3$ is presented. This titrimetric detn. is used in connection with estn. of dissolved O in concn. of 0.001 ppm with accuracy of ±0.0001 ppm. Amperometric detection circuit is given as well as other current methods for detection of end point of aq. I/thiosulfate titrations.—*CA*

Anionic Softening of Water with Strong-Base Anion-Exchanges Resins. R. KUNIN & F. X. MCGARVEY. Ind. Eng. Chem., **47**:1230 ('55). Highly porous analogs of strong-base anion-exchange resins are more effective in picking up fluoride than are conventional resins. Countercurrent operation has advantages of low fluoride leakage and high capacities. HCO_3 ion can be removed more effectively from soln. by using combination of alkali and salt as regenerant. In case of sulfide removal, capacity is markedly dependent on influent pH and regeneration efficiency is improved greatly by use of $NaHCO_3$. Capacity at pH 10 is several fold that at pH 7.0.—*CA*

TASTE AND ODOR

The Use of Chlorine Dioxide in Tomsk Water Supply System With the Purpose of Dimination of Chlorophenolic Odor. A. L. SEGELMAN. Gigiena i Sanit., No. 10: 46 (USSR), ('54). Results are shown on expts. with treatment of natural water available for municipal supply of Tomsk with either chlorinated lime or ClO_2 in attempt to control obnoxious odor of phenolic sub-

(Continued on page 84 P&R)



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(Continued from page 82 P&R)

stances which appear periodically in waters. At 0.7–1.5 mg/l. of Cl input, in form of ClO_2, complete elimination of chlorophenolic odor was attained. Chlorinated lime gave very poor control of odor. Bacterial count was similarly satisfactory after ClO_2 treatment.—*CA*

Tastes and Odors Produced by Chlorination of Simple Nitrogenous Compounds. R. S. INGOLS, H. W. HODGDEN, & J. C. HILDEBRAND. J. Agr. Food Chem., **2**:1068 ('54). Of 25 amino acids and related compds. studied, alanine, phenylalanine, arginine, and proline produced taste upon reaction with hypochlorous acid and monochloramine, and proline and phenylalanine produced taste with chlorine dioxide. Proline and phenylalanine have taste threshold concns. of few parts per billion. All 4 amino acids are found in common proteins. Other amino acids have been found in lake water in these concns. Attempts to find or produce any of 4 amino acids in waters about Atlanta during summer of 1952 were unsuccessful.—*CA*

Preliminary Taste and Odor Survey at Gary, Indiana. R. KINSER. Taste and Odor Control J., **21**:1 ('55). The Gary-Hobart Water Corp. was formed in April, 1951. When pumping and distribution facilities of the 2 communities were purchased, company immediately initiated plans for modern purification plant which was completed 3 years later. New filtration plant includes 2 slow mixing basins equipped with Dorr flocculators, settling basin and 6 rapid sand filters. Settling basin consists of 2 units each having 2 stories in height with water depth in each level of 16 ft. Water flows down to lower level and then upward. Each filter has maximum rated capacity of 12 mgd so that plant is capable of delivering maximum of 72 mgd. Chlorine alum and Aqua Nuchar are applied to raw water and chlorine and ammonia are applied to clear well. Water leaving plant carries chlora-

(Continued on page 86 P&R)

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ESTABLISHED 1906—47 YEARS OF SERVICE

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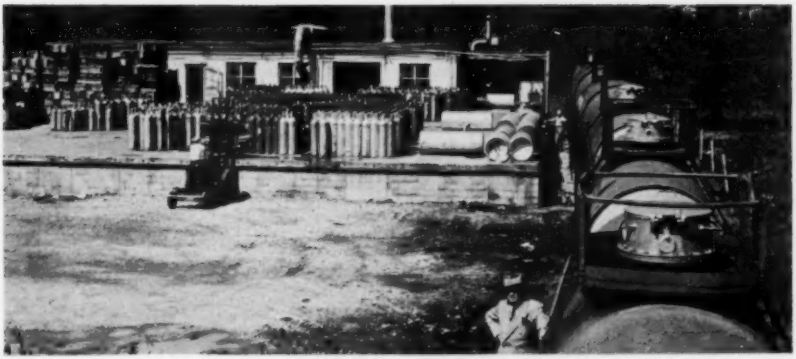

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Idlewood 1443, 1444

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Tele—North Dade 6-6288
or Dial 81-6-6288

(Continued from page 84 P&R)

mine residual of 1.0–1.2 ppm. Taste tests indicated that basic threshold value of 4 or less would be within palatable limits. Odors of raw water range from 10–14, and 15 pmg of Nuchar produced basic odor of 3–5. At these levels no consumer complaints were received. Plant is new and further experiences may dictate changes in chemical treatment.—*PHEA*

The Causes of the Objectionable Odor and Taste of Bank-filtered Water on the Lower Rhine. Methods and Results. J. HALLUTA. Gas- u. Wasserfach (Ger.), **96**: 451 ('55). In many locations along lower Rhine, bank-filtered water has objectionable odor and taste throughout year. With view to detg. sources of this contamination, series of sampling locations was chosen, alternating between wells on right and left bank. On same day samples were taken for analysis from middle of river. Where results for 3 different sampling locations varied widely for given constituent, this sometimes indicated proximity of contamination. However, NH_3 content was fairly uniform and could not be used for this purpose. Org. impurities in water were concd. by filtration of water through active C, with later extn. Ultimate analyses are given for material extd from active C with Et_2O, C_6H_{12}, C_6H_6, and $CHCl_3$; paper chromatography was also applied to exts. Wide variety of org. bases, amphoteric (org.) compds., neutral org. compds., phenolic compds., and org. acid compds. were identified, but no quant. estn. of relative amts. is possible. However, in few instances, use of such methods permitted fixing of source of specific contamination. Ultraviolet light indicated appreciable amt. of oil in ext. Amt. of ether-sol. ext. was about 10 times as great in river water as in bank-filtered water; fraction of neutral org. compds. and those fluorescing in ultraviolet was also found to be greater in river water. Phenol content and that of org. acids was greater in bank-filtered water.—*CA*

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Correspondence

USPHS Research Grants

To the Editor:

It has been called to my attention by Dr. Charles D. Gates, School of Civil Engineering, Cornell University, that, in my article on "US Public Health Service Research Grants" (November 1955 JOURNAL), I had not included his project in the table on p. 1076. This was an oversight, and I should therefore like you to know, for your records, that Dr. Gates has an active Public Health Service–supported project designated RG-4071 and entitled, "Effect of Synthetic Detergents on the Removal of Bacteria by Sand Filtration." Dr. Gates is principal investigator of this study, which was approved for a 3-year period beginning Oct. 1, 1953.

IRVING GERRING

Bethesda, Md.
Feb. 13, 1956

Prodigiously Pink

To the Editor:

"Whatallergy" can you make out of this one? After reading about the pink britches in the October 1955 (p. 46 P&R), November 1955 (p. 76 P&R), and January 1956 (p. 50 P&R) issues, I remembered the case of the pink shirting goods in the bleachery of a prominent shirtmaker in the United States. The management was sorely tried. Bale upon bale of "gray goods" was pinkish upon receipt. After much talk and some experimentation, it was decided the trouble was caused by *Bacillus prodigiosus*, an organism that thrives in the presence of starch. Pure cultures of *B. prodigiosus*, when planted on swatches of gray goods, produced a color identical to the one giving the difficulty. Incidentally, chlorine kills the organisms and permanently bleaches the color produced by them. Would you call this "shirtology" or "prodigiosomania"?

A. E. GRIFFIN

Belleville, N.J.
Mar. 13, 1956

Whatever you call it, this probably explains the pink shirt fad!—ED.

Basic English

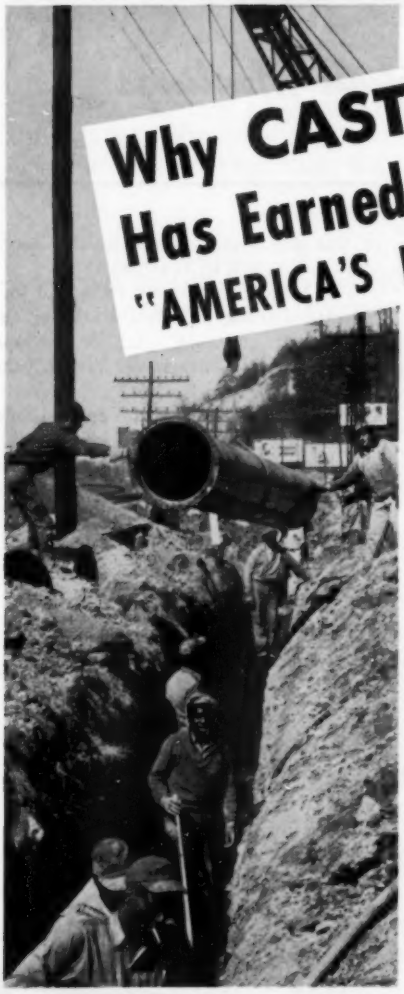
To the Editor:

Your "London Britches" letter of January (p. 50 P&R) really aroused not only my interest and sympathy but my instinct for the preservation of the purity of the mother tongue. Bad enough to resort to phony phonetics for "breeches," but, unless you left us behind in your editorial comment, the word you intended was "fundament," not "foundation."

LOREN E. BLAKELEY

Santa Ana, Calif.
Mar. 2, 1956

Unwilling to admit that we ever left a reader behind, we'll have to settle for being caught off base on something mighty elemental.—ED.



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Actual records of more than 100 large cities which have water systems 100 years and older and still in service, prove that Cast Iron pipe is lowest in cost over the years.

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because of its effective resistance to corrosion and its wide margins of safety in strength to withstand impact, beam and crushing stresses.

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and effect these savings for your community.

Our Company does not manufacture pipe but has long supplied the nation's leading pipe manufacturers with quality iron from which pipe is made.

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Section Meetings

Illinois Section: The Illinois Section held its annual conference at the La Salle Hotel in Chicago Mar. 21–23, 1956. There were 468 members, guests, and manufacturers' representatives in attendance. The Section was delighted to have President Amsbary present as he has been one of its members since college days. In a talk at the business luncheon, he urged everyone to get behind the highway bill before Congress. A resolution to this effect was passed by the Section and telegraphed to Washington.

The Fuller Award for 1956 will go to Edward E. Alt. Gerald L. Davis was elected chairman, C. L. Baylor vice-chairman, and Warren W. Wolfe, junior trustee.

Mike Foley, head of the entertainment committee, provided an elaborate cocktail party on Thursday evening, Mar. 22. The annual banquet was attended by 318

(*Continued on page 92 P&R*)

BELL JOINT LEAK CLAMPS

GASKET SEALER COMPOUND

C-I-60 CAST IRON BOLTS

Carson glands and bolts made of corrosion-resistant C-I-60 cast iron—last as long as cast iron pipe. Glands accommodate variations in pipe dimensions, insure uniform compression of rubber gasket.

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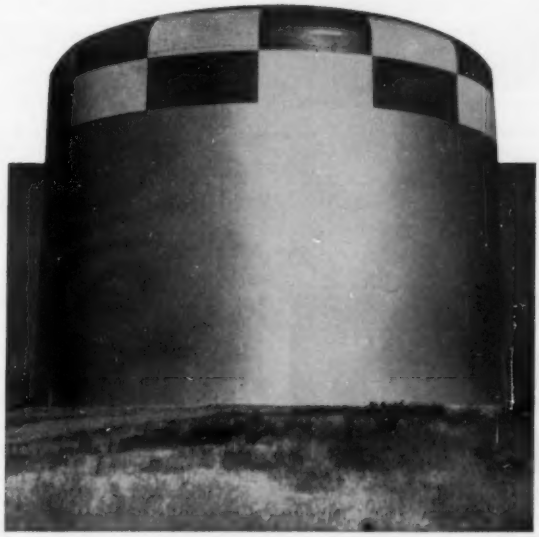
WATER LEVEL IN THIS "AMERICA'S LARGEST" STANDPIPE IS CONTROLLED BY A 20-inch ROSS DOUBLE ACTING ALTITUDE VALVE.



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ROSS VALVE MANUFACTURING CO., INC.

P. O. Box 593 Troy, N. Y.

Section Meetings

(Continued from page 90 P&R)

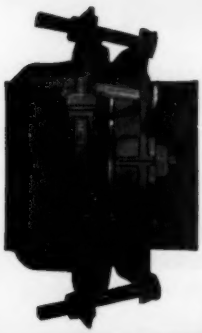
members and guests. Life Membership was conferred upon W. W. Polk, J. A. Holmes, and W. M. Olson. The special guest speaker of the evening was Warren Foster, of the Coca-Cola Co., Atlanta, who gave a most interesting and humorous talk. An employee of the Chicago filtration plant sang several opera numbers, which the audience received enthusiastically.

Twenty-two papers were given during the 3-day conference. These covered many aspects of water works practice—filtration, softening, pumping, air conditioning, finance, public relations, job training, and public speaking.

A special rendezvous room was introduced for the ladies' entertainment, and they were also taken to see "Oklahoma."

DEWEY W. JOHNSON
Secretary-Treasurer

FOR REPAIRING BELL AND SPIGOT JOINT LEAKS...



The only clamp with these two important features. Gasket is completely SEALED. Massive ¾" electroplated bolts. 2"—42" incl.

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SOUTH BEND 21, INDIANA, U.S.A.

Indiana Section: The 48th annual Indiana Section meeting got under way following an early-bird luncheon on Wednesday, Feb. 8, when Chairman George G. Fassnacht called for order and gave a brief address of welcome to the membership. The technical program included such varied topics as leak surveys, treatment chemicals, nuisance organisms, geophysics, ground water pumping tests, and resources policies. A great deal of sorrow was caused by the fact that Fred P. Stradling, manager, Bristol County (R.I.) Water Co., had suffered a severe stroke on his way to the meeting and was unable to speak on the subject of emergency water works operation. His place on the program was very capably filled by Vice-President Weir who talked on central dispatching at Atlanta.

A capacity crowd enjoyed the Thursday evening banquet, Club Room entertainment, and dancing. They enthusiastically received the nomination of Harold S. Griswold for the George Warren Fuller Award. The officers chosen for the coming year were: chairman—Everett Robbins, superintendent, Speedway Water Works; vice-chairman, Ray G. Rinehart, J. B. Clow & Sons, South Bend; secretary-treasurer—Robert J. Becker, Indianapolis Water Co.; and assistant secretary-treasurer—Chester H. Canham, State Board of Health, Indianapolis.

The final session on Friday morning was a combination breakfast and management problems forum. Howard S. Morse, president, Indianapolis Water Co., presided over the open discussions on charges for main extensions, relocation problems, voluntary certification of operators, and personnel training and job evaluation.

The total registration was 421, including 85 wives. Although the 48th annual Indiana Section meeting did not set any attendance record, it certainly qualified as one of the finest.

ROBERT J. BECKER
Secretary-Treasurer

TIGHT IN THE JOINTS?
YOU BET!

Getting tight joints is simple—USE STEEL PIPE. Steel water pipe *assures* bottle-tight joints for the life of the line. When you have steel-tight joints, there is no need to over-design water pipe lines to take care of costly needless water waste. Tight joints cost less to begin with—and actually *save* you money through the years. It's another good reason why you're so smart to specify steel pipe.

"WHEREVER WATER FLOWS—STEEL PIPES IT BEST"

STEEL PLATE FABRICATORS ASSOCIATION

79 W. MONROE ST., CHICAGO 3, ILL.

(Continued from page 52 P&R)

Certification of sanitary engineers is a leading objective of the new American Sanitary Engineering Intersociety Board organized by representatives of APHA, ASCE, AWWA, FSIWA, and the American Society for Engineering Education (see photo below). Created "to improve the practice, elevate the standards, and advance the cause of sanitary engineering; and to grant and issue to engineers, duly licensed by law to practice engineering, certificates of special knowledge in sanitary engineering or in any field thereof," the board consists of Chairman Earnest Boyce, head, Dept. of Civil Engineering, University of Michigan, Ann Arbor; Vice-Chairman W. A. Hardenbergh, editor of *Public Works Magazine,* Ridgewood, N.J.; R. S. Rankin, manager, Sanitary Engineering Div., Dorr-Oliver Inc., Stamford, Conn.; and Francis B. Elder, engineering associate, American Public Health Assn., New York. Development of the certification process will be the task of the Sanitary Engineering Specialty Committee, headed by AWWA Executive Assistant Secretary Raymond J. Faust.

Shown signing the articles of incorporation of the American Sanitary Engineering Intersociety Board is Chairman Earnest Boyce. Seated (left to right) are: Thomas R. Camp, Rolf Eliassen, Chairman Boyce, Vice-Chairman W. A. Hardenbergh, Robert E. Stiemke, Dwight F. Metzler, and Gilbert H. Dunstan. Standing (left to right) are: J. E. Kiker, R. E. Lawrence, Francis B. Elder, Clarence I. Sterling, Alvin F. Meyer Jr., Wendell R. LaDue, George O. Pierce, and R. S. Rankin.

(Continued on page 96 P&R)

NO FRILLS..
All Business

CHAPMAN MOTOR UNITS

Just look at them . . . inside as well as out. You'll find that Chapman Motor Units are not only rugged in construction, *they're simple in design.* In fact, a Chapman Motor Unit has approximately *half as many parts* as any other unit.

This simplicity means better, easier operation and lower maintenance costs. It means longer life with fewer repairs.

With Chapman Motor Units your valves seat tight . . . but never too tight. Micrometer adjustment on limit switch insures exact tightness presetting. Drift is eliminated. Lash is slashed. Complete operation by low speed motors is always smooth, accurate and trouble free.

Use them in any position. Quiet, rugged stub-tooth gears require no grease or oil. Use them under the most adverse conditions. They're weatherproof, steamtight, dependable.

Installation is quick and easy. Chapman Motor Units and Floorstands are wired and ready to tie in with your leads. Just hitch them up. You're in business.

Get the whole interesting story in our newest catalog 51. Write for it, your copy, now.

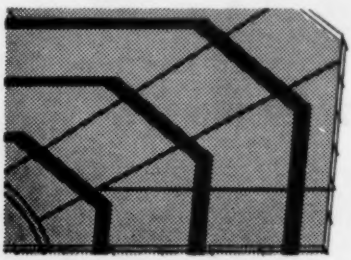
The CHAPMAN VALVE Mfg. Co.
INDIAN ORCHARD, MASS.

(Continued from page 94 P&R)

Water works woman in spite of herself is Mrs. Ruby Bonham of Mokane, Mo., whose private line started becoming a party line some 40 years ago and is now, by official definition, a public line. Actually, it was Mrs. Bonham's father who blundered into the utility business back in 1919, when he put in a pipeline to his well and was nice enough to permit some of his neighbors to hook on to his system. Later, when he laid another pipeline from the well to his office in town, there were more thirsty neighbors who found the line convenient—so convenient, in fact, that the local high school and a locker plant preferred not to disturb anyone at the time they made their own taps.

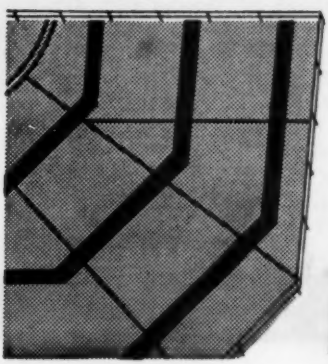
Since she inherited the system 5 years ago, Mrs. Bonham has been trying to operate it at long distance—from Denver, Colo., where she now resides. Having found that her net earnings for that period averaged approximately $10 per year, she boosted rates from $2.00 to $2.50 per month, an action that was greeted with anything but good neighborliness by her 39 accounts. Having had no luck in her attempt to sell the system to the town (population 500) for a bargain price of $8,000, she finally asked the Missouri Public Service Commission to let her just quit. That brought an official protest from 110 per cent of the customers on her books—four free riders apparently deciding that water was even more important than money—or pride. The outcome of the hearing has yet to be reported, but even if Mrs. Bonham is unsuccessful in dewater-

(Continued on page 98 P&R)



This is the experience of a plant with a rated capacity of 20 m.g.d. river water (high mine waste content.) N-Sol Activated Silica used with alum produces large, highly active floc that enmeshes suspended matter and settles rapidly. Thus, longer filter runs can be obtained.

N-Sol Activated Silica Sol increases filter runs **35%**



N-Sol is prepared in your plant with N Sodium Silicate ($Na_2O:3.22SiO_2$) and a reacting chemical.

Ask for sample of N and information on various N-Sol Processes. No charge for license under our N-Sol patents.

Philadelphia Quartz Company
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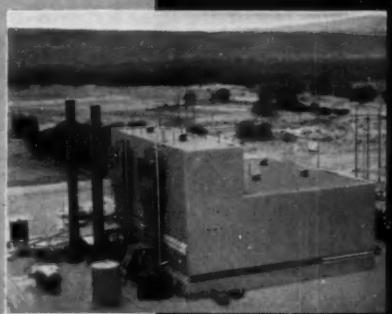
N-Sol Processes
PQ SOLUBLE SILICATES

four different water supplies from one water treatment plant by GENERAL FILTER

The Plains Electric Generation and Transmission Co-operative recently completed at Algodones, New Mexico, provides 30,000 kilowatts per hour to Southwest consumers.



A water treatment plant capable of providing suitable water in sufficient quantities for four different supplies was required by the consulting engineers:

- COOLING WATER for the condensation of turbine steam.
- SANITARY WATER for drinking and sanitation.
- MAKE-UP WATER for the boilers.
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With the system installed one operator can check, alter and control the treatment process from a master control panel . . . confident of complete dependability . . . minimum maintenance.

AERATORS • FILTERS • TASTE AND ODOR • ALKALINITY CONTROL • HIGH CAPACITY RESINOUS ZEOLITE • IRON RUST REMOVAL • DEMINERALIZATION • SOFTENERS

Ask for recommendations for a water treatment plant "job-engineered" to your requirements . . . a fast, efficient, economical system by General Filter.

General Filter Company
AMES, IOWA

. . . *better water*

(Continued from page 96 P&R)

worksing herself, she will at least have turned up $120 more in annual income —a 1,200 per cent increase in her net income and 1½ per cent additional return on her valuation. A few more protestants, as a matter of fact, might make her change her mind and join AWWA.

A dog's life these days seems to be improving far faster even than our own. Just last month, for instance, we reported practically a trend toward chrome-plated hydrants and the month before that, an allout campaign by Dothan, Ala., meter readers to be considerate of customary canines by using their proper names. Now, from Des Moines and Indianapolis comes word of a still lower bow to Bowser. At the Iowa Power & Light Co., meter readers are filling their pockets with "Lolli-Pups" and at the Indianapolis Water Co., with "Yummies"—dog candy, that is—to pacify and befriend the public's puppies. All well and good public relations we suppose, but having just a wee bit of remembrance of appeasement past, we wonder if the next step may not be a requirement that meter readers wear shorts, to make their legs more available, if not attractive, to hungry hounds. After all, it really would be a dog's life to have to live on candy—even candy containing "nutritional elements such as proteins, fats, vitamins, minerals, medicated charcoal, and chlorophyllins." A dog has to have fresh meat—meater reader, that is—rare!

(Continued on page 100 P&R)

Type SM with Worm Gear Drive on Butterfly Valve.

Limitorque® VALVE CONTROLS

From coast to coast, hundreds of LimiTorque Controls are in service in central stations and power plants for automatic or push-button operation of valves up to 120 inch diameter. Why is acceptance so widespread? Because LimiTorque Operators are designed to provide dependable, safe and sure valve actuation at all times.

LimiTorque is self-contained and is applicable to all makes of valves. Any available power source may be used to actuate the operator: Electricity, water, air, oil, gas, and are readily adapted to Microwave Control.

A feature of LimiTorque is the torque limit switch which controls the closing thrust on the valve stem and prevents damage to valve operating parts.

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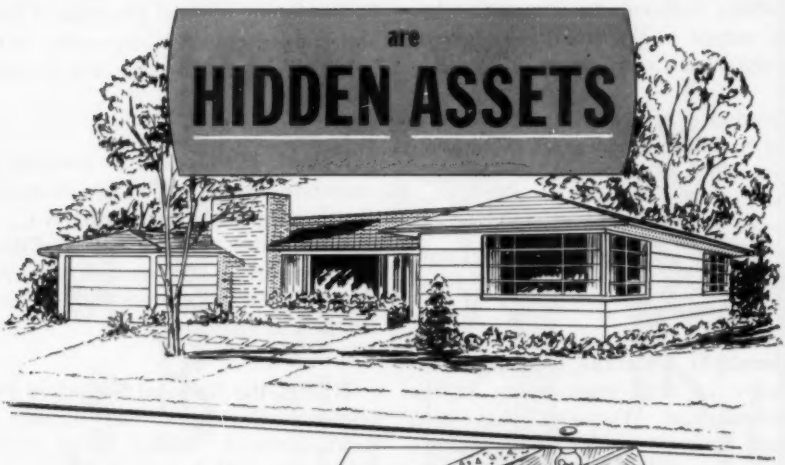

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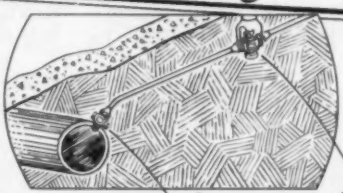

You don't see the HAYS Corporation and Curb Stops after you have them installed. But they're working for you, saving expensive digging and replacement, literally *hidden assets.*

All plugs are individually ground in for perfect fit and specially lubricated for easy turning year after year, generation after generation. HAYS craftsmen are trained to uphold a tradition more than eighty years old for dependable precision products.

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HAYS®

WATER WORKS PRODUCTS

HAYS MANUFACTURING CO.

ERIE, PA.

(Continued from page 98 P&R)

Thomas W. Moses, assistant to the president, Indianapolis Water Co., has been named to the Indiana Industrial Development Commission.

Graduate study programs leading to M.S. and Ph.D. degrees in sanitary engineering are announced by the University of Florida. A number of research assistantships are available. For further information, write: Dean, Graduate School, University of Florida, Gainesville.

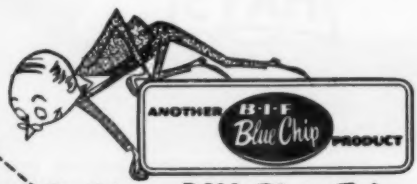
Gerald H. Teletzke, formerly an instructor in civil engineering at the University of Wisconsin, has been named assistant professor of sanitary engineering at Purdue University. In addition to teaching, he will take part in developing a broad program of basic and applied research, especially in the field of industrial- and atomic-waste disposal.

Robert H. Hood has resigned as executive editor of *The Municipal South* magazine, Charlotte, N.C., to take a sales position with Edison Voicewriters. His successor is Andrew Hewitt, vice-president of Clark-Smith Publishing Co.

NSPE, the National Society of Professional Engineers, has moved its headquarters to 2029 K Street, N.W., Washington, D.C.

(Continued on page 102 P&R)

When To Use



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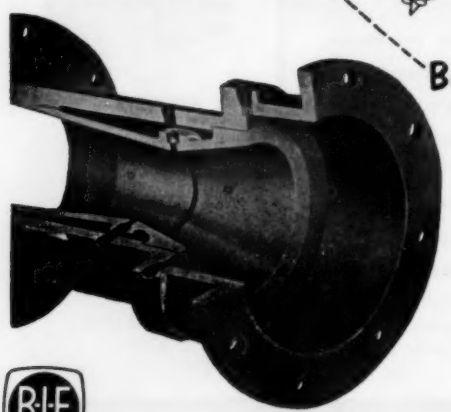

- Use Dall Tubes when you need compact, minimum-cost installations: (average laying length only 1½ times line size).
- Use Dall Tubes when you need sustained metering accuracy: (smooth tapered throat is self-scouring, dimensionally stable).
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DO-IT-YOURSELF *in 3 Easy Steps*

THE "*Flexible*" WAY!

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2 Cut line at desired exit and — couple on riser to permit deposit and tool to emerge from line above ground level.

3 Open valve. The water pressure and scraper does the rest.

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(Distributors in Principal Cities)

AMERICA'S LARGEST LINE OF PIPE CLEANING TOOLS AND EQUIPMENT

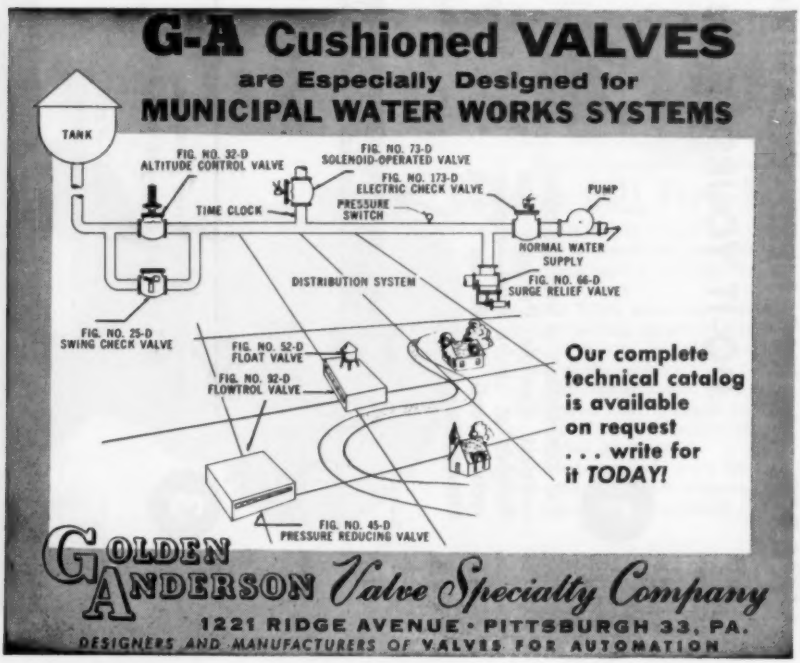
(Continued from page 100 P&R)

Henry Berry, twice chairman of the Metropolitan Water Board, London, England, died Feb. 14, 1956, at the age

of 73. Born at Woolwich, Kent, in 1883, he was educated at Woolwich Polytechnic and Goldsmiths College, New Cross. As chairman of the Metropolitan Water Board in 1940–46, he was responsible for the water supply of London during World War II. For this and his many other public services—Labour Member of Parliament, 1945–50; member of the London County Council (elected vice-chairman in 1940); Woolwich Borough councillor—he was named a Commander of the Order of the British Empire in 1952.

Joining AWWA in 1944, he was made an Honorary Member in 1949. He was also a long-time member of the British Waterworks Assn., serving as its president in 1948–49. In addition, he was a member of the Institution of Mechanical Engineers, an associate of the Institution of Structural Engineers, and a fellow of the Royal Society of Arts.

(Continued on page 104 P&R)



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Surgeability is defined as stability of performance under rapidly changing and unpredictable conditions including flow. This characteristic is vitally important in clarification and cold process softening installations. Surgeability is designed and built into the Graver Reactivator®.

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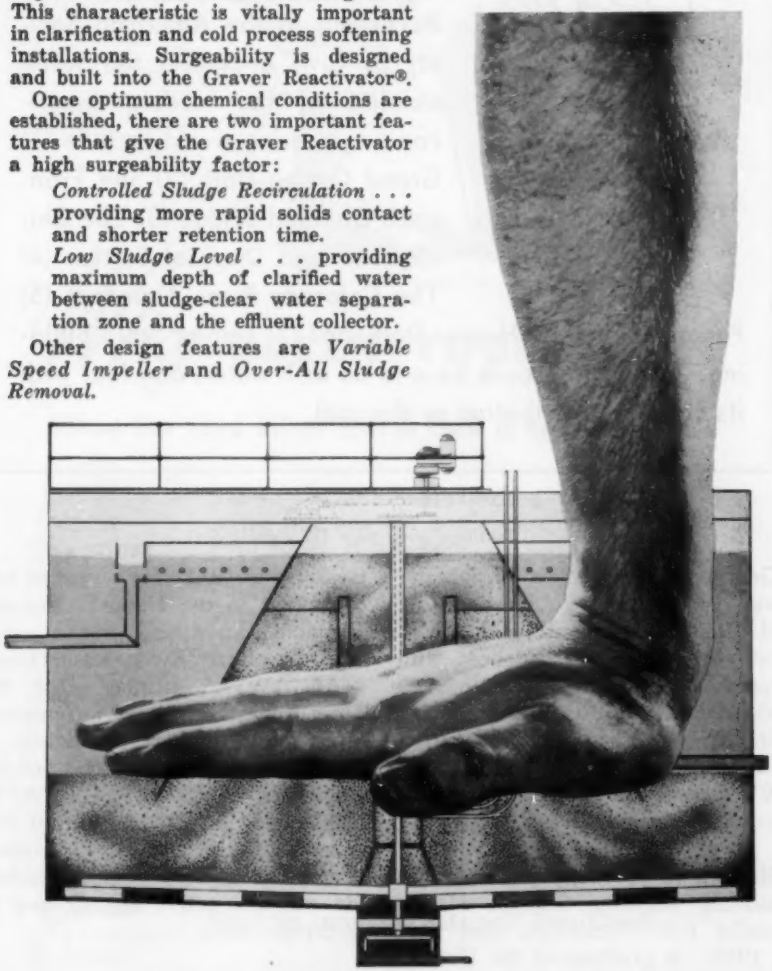

WRITE FOR DESCRIPTIVE CATALOGUE WC-103A

Department NK

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According to the American Society of Civil Engineers the seven wonders of the modern American engineering world include (1) Grand Coulee Dam (2) San Francisco Oakland Bridge (3) The Chicago Sewage Disposal System (4) The Colorado River Aqueduct (5) Panama Canal (6) Hoover Dam, and (7) Empire State Building. Six of the seven have to do with water, and four with its storage, distribution or disposal.

(*Continued from page 102 P&R*)

George E. Boyd, New York water works representative for Koppers Co., died Mar. 14, 1956, at his home in New York City. He had been with Koppers since its acquisition in 1946 of the Wailes Dove-Hermiston Corp., which Mr. Boyd had served as district sales manager from 1926 on. An AWWA member since 1931, Mr. Boyd also belonged to ASCE.

Nathan B. Jacobs, president of the consulting engineer firm of Morris Knowles Inc., Pittsburgh, died Feb. 14, 1956. A graduate of the University of Pittsburgh, he was a registered professional engineer in Pennsylvania and New York. He joined Morris Knowles in 1914, becoming vice-president in 1921 and president and treasurer in 1932. He served as water consultant to the National Resources Planning Board and was associated with Delaware River Basin studies.

An AWWA member since 1930, Mr. Jacobs belonged to numerous other professional organizations, including American Inst. of Consulting Engineers, APHA, ASCE, ASTM, Engineering Society of Western Pennsylvania, NSPE, and Pennsylvania Water Works Assn. (vice-president). He was also active in civic and philanthropic work.

Malcolm S. McIlroy, professor of electrical engineering at Cornell University, Ithaca, N.Y., died Mar. 4, 1956, at the age of 53. Born at Rochester, N.Y., in 1902, he received a de-

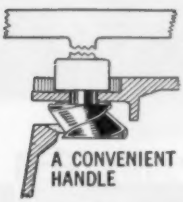
(*Continued on page 106 P&R*)

Why BREAK YOUR BACK?

When the Ford Lifter Worm Lock is so easy to use

A STRONG LOCK

A POWERFUL SCREW-JACK


A CONVENIENT HANDLE

Snow, ice and dirt tending to hold down meter box lids are easily conquered with the Ford Lifter Worm Lock.

This simple mechanism, operating like an auto-jack, has a tremendous lifting force that breaks any seal around the edges of your covers.

It's handy, too, because it locks and unlocks your lid to prevent tampering. It offers extra safety because an unlocked lid is detected at a glance.

The key which operates the Lifter Worm Lock serves as a handle to lift the lid, saving time and keeping hands clean.

Send for complete data and Free Catalog.

THE FORD METER BOX COMPANY, INC.
WABASH, INDIANA

FOR BETTER WATER SERVICES FORD

(Continued from page 104 P&R)

gree in electrical engineering from Cornell in 1923. After service with several private companies, he became a faculty member at Massachusetts Inst. of Technology in 1937, returning to teach at Cornell in 1947. (He was appointed assistant dean of the Engineering College there in 1952, but was unable to serve for reasons of health.) He also acted as consultant to Standard Electric Time Co., Springfield, Mass., the manufacturer of the fluid network analyzer for the development of which Dr. McIlroy was widely known. An AWWA member since 1949, he was awarded the Goodell Prize in 1951 for his significant article (April 1950 JOURNAL AWWA) on this device. His death occurs at a time when his network analyzers are just beginning to be placed in operation by some of the nation's larger cities.

Lowell E. Northrop, secretary of the California Water Assn., died at Los Angeles Jan. 8, 1956, at the age of 68. Born in Reno, Nev., in 1888, he attended the California Inst. of Technology (then called Troop Polytechnic Inst.). In 1911 he joined Neptune Meter Co., where he remained until his retirement in 1953. Throughout his sales career he was active in various professional and technical societies in the West, and was a life member of the Arizona Sewage & Water Works Assn., as well as an AWWA member since 1929.

(Continued on page 108 P&R)

ELEVATED TANKS

For almost a century Cole elevated tanks have been helping provide uniform water pressure, fire protection and adequate water reserve in scores of American cities.

Capacities 5,000 to 2,000,000 gallons—with hemispherical, ellipsoidal or conical bottoms. Also flat-bottom tanks for standpipe storage. Correctly built in accordance with AWWA specifications.

We invite your inquiries. State capacity, height to bottom, and location.

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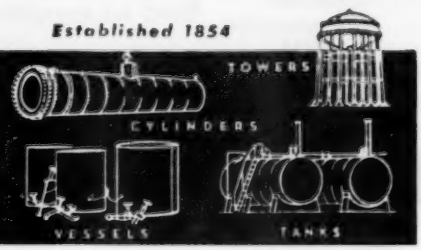
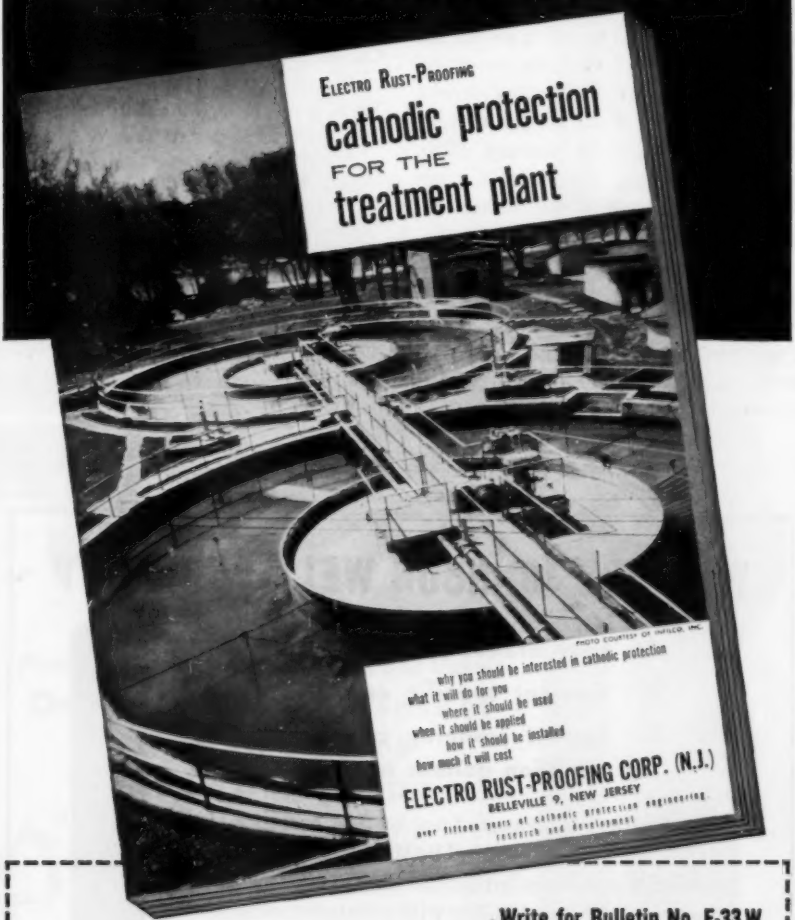


THIS **FREE** BULLETIN CAN SHOW YOU
HOW TO STOP CORROSION IN YOUR PLANT



Write for Bulletin No. E-33W

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E-33

(Continued from page 106 P&R)

Raymond W. Sparling, for many years president of Sparling Meter Co., Los Angeles, died Feb. 5, 1956, at his beach home on Balboa Island, Calif. He was 69. In 1919 he organized the Sparling Meter Co. to sell a meter for irrigation water. Later the company branched out into the water works and other fields. Following a merger with another concern in January, 1956, Mr. Sparling's son, Raymond C., became president, while the father remained as vice-president.

Edward C. Trax, city chemist, McKeesport, Pa., and a consulting chemist for filtration plants and industrial water systems, died Feb. 26, 1956, at his home in Elizabeth Township. He was 74. Born in Library, Pa., he became assistant chemist for Pittsburgh Water Co. after graduation from the University of Pittsburgh in 1906. The following year he accepted the post of chemist analyst at Gubick-Henderson Co. in the same city. He took charge of the McKeesport Filtration Plant in 1908, a position he held until his death.

A Life Member of AWWA (joined in 1911), Mr. Trax was given the Fuller Award by the Central States Section in 1939. He held the office of chairman both in that section and in the Western Pennsylvania Section, and was also a director representing the latter. Mr. Trax was likewise a member of the Pennsylvania Water Works Operators Assn. and had served as its president.

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2. **Greater specific capacity.**
3. **Lowest pumping cost per million gallons of water.**

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NEW MEMBERS

Applications received Mar. 1–31, 1956

Anderson, Albert H., Supt., Water & Sewage, Box 183, Scranton, Iowa (Apr. '56) *M*

Arbuckle, Edward; *see* Jefferson (Iowa) Water Works

Ashby, John O., Supt., Water & Sewage, Arp, Tex. (Apr. '56)

Ashline, Robert R., Corrosion Engr., Dept. of Water & Power, 410 Decommun St., Los Angeles 12, Calif. (Apr. '56)

Aspen Water Co., Frederick Hendy, Pres., Box 205, Aspen, Colo. (Corp. M. Apr. '56) *PD*

Atwell, John L., Asst. Secy.-Treas., National Water Main Cleaning Co., 50 Church St., New York, N.Y. (Apr. '56) *MD*

Avent, Thomas Polk, Supt., Water Works, Bolivar, Tenn. (Apr. '56)

Babb, Donald R., Water Supt., 134 S. Fillmore, Cambridge, Minn. (Affil. Apr. '56) *M*

Baird, M. C., Sales Engr., Trinity Valley Iron & Steel Co., 3400 Bryce St., Fort Worth, Tex. (Apr. '56)

Baker, Robert Henry, Secy., Graves Elec. Supply Co., Box 2361, Greenville, S.C. (Apr. '56) *PD*

Barber, Carl H., Sales Repr., International Minerals & Chem. Corp., 61 Broadway, New York 6, N.Y. (Apr. '56) *P*

Barlow, Willis D., Engr., L. E. Wooten & Co., 3035 Medlin Dr., Raleigh, N.C. (Apr. '56) *RPD*

Beaumont, Virtus, Supt., Water Works, 22 N. Main St., Albia, Iowa (Apr. '56) *MPD*

Beebe, Charles H., Civ. Engr., The Harwood Beebe Co., Box 2405 Sta. A, Spartanburg, S.C. (Apr. '56) *RPD*

Beene, William H., Jr.; *see* Hixson (Tenn.) Utility Dist.

Bell, Phillip A., Sales Engr., Kenneth Anderson Co., 140 Randolph St., Detroit 26, Mich. (Apr. '56) *MD*

Berry, H. Frank, Gen. Mgr., Utilities Dept., Etowah, Tenn. (Apr. '56) *M*

Bespalow, Eugene F., Vice-Pres. & Chief Engr., Choctaw, Inc., Box 2057, Memphis 1, Tenn. (Apr. '56) *D*

Bird, Thomas H., Office Mgr., Water Works, Rm. 102, 68 Mitchell St., S.W., Atlanta, Ga. (Apr. '56) *M*

Blair, George Y., Civ. Engr., George S. Nolte, Civ. Engr., 310 University Ave., Palo Alto, Calif. (Apr. '56) *RPD*

Bradstock, Robert K., Water Distr. Supervisor, Water Dept., 29th & Cambria, Philadelphia, Pa. (Apr. '56) *D*

Briscoe, John T., Supt., Water, Light & Gas Com., Monroe, Ga. (Apr. '56) *MD*

Brown, Barney B., Civ. Engr., K. W. Lefever Cons. Engr., 401 Victory St., Little Rock, Ark. (Apr. '56)

Brown, Calvin G., City Engr., Municipal Bldg., Aberdeen, S.D. (Apr. '56) *MRD*

Brunner, Kenneth, Civ. Engr., 2918 Gilroy St., Los Angeles 39, Calif. (Apr. '56) *MRPD*

Bryant, E. A., Supt., Water & Sewage, Beeville, Tex. (Apr. '56) *M*

Buchmueller, Milton, Asst. Div. Engr., Design & Constr., Water Div., 1640 S. Kingshighway, St. Louis 10, Mo. (Apr. '56) *MP*

Buckner, B. L., Supt., Water Works, 108 E. Broadway, Pocahontas, Ark. (Apr. '56) *MPD*

Budd, Bernard T.; *see* Parsons (Kan.) Water Dept.

Budd, William E., Mgr., Development Sec., Dorr-Oliver Inc., Barry Pl., Stamford, Conn. (Apr. '56) *MP*

Case, C. William, Partner, Todgham & Case, Box 94, 21—7th St., Chatham, Ont. (Apr. '56)

Coffeyville, City of, Fred L. Kramer, Supt., Water Dept., Coffeyville, Kan. (Corp. M. Apr. '56) *MPD*

Cooley, Floyd D., Foreman, Los Angeles Water Dept., Box 2152 South Annex, Van Nuys, Calif. (Apr. '56) *MD*

Cousins, James C., Supt., Mauldin, Simpsonville, Fountain Inn Water Dist., Box 356, Simpsonville, S.C. (Apr. '56) *D*

Crump, Stott N., Chief Engr., Water Works & San. Sewer Board, Montgomery, Ala. (Apr. '56) *MD*

Decker, Fred W., Asst. Prof., Dept. of Physics, Oregon State College, Corvallis, Ore. (Apr. '56) *R*

Dillard, R. S., Sr., Water Supt., Andrews, Tex. (Apr. '56) *MR*

Drechsel, Heinz R., Foreman, Water Systems, Bethlehem Steel Co., Johnstown, Pa. (Apr. '56) *PD*

Duser, August G.; *see* North Judson (Ind.) Water Dept.

Edwards, Carl I., Supt., Pequannock Township Water Dept., 2 Sherman Ave., Pompton Plains, N.J. (Apr. '56)

Erickson, M., Chief Filter Operator, Water Dept., 555 Lincoln, Evanston, Ill. (Apr. '56) *P*

Faulkender, Clyde R., Tech. Director, Charmin Paper Mills Inc., Green Bay, Wis. (Apr. '56) *P*

Fernandez M., Arturo M., Chief Engr., Marianao Water Works, Cia de Acueductos de Cuba, Apt. 25, Marianao, Havana, Cuba (Apr. '56)

Fleckenstein, William C., Supt. of Operations, Florida Utilities Corp., 520 Park Ave., Winter Park, Fla. (Apr. '56) *MD*

Foehrenbacher, Henry; *see* St. Cloud (Minn.) Water-Sewage Utility

Foll, Ray R., Southern Mill Supplies, 3258 Chippewa St., New Orleans, La. (Apr. '56)

Foster, John W., Ground Water Geologist, William F. Guyton & Assocs., 307 W. 12th St., Austin, Tex. (Apr. '56) *R*

Galloway, James; *see* Park Ridge (Ill.)

General Elec. Co. Range & Water Heater Dept., Bohdan Hurko, Water Processing System Engr., Appliance Park, Louisville 1, Ky. (Corp. M. Apr. '56) *RPD*

Gibson, W. R., Salesman, Badger Meter Mfg. Co., Box 1897, Greenville, S.C. (Apr. '56) *D*

Gillam, Charles H., Student, Univ. of Washington, 630—3rd W., Seattle 99, Wash. (Jr. M. Apr. '56) *MRPD*

Glass, Donald L., Asst. Chemist, Water Works, 2217 Scioto Trail, Portsmouth, Ohio (Apr. '56) *P*

Gorton, Melvin B., Production Mgr., Rockwell Meters Inc., Uniontown, Pa. (Apr. '56) *D*

Gosselin, Andre, Civ. Engr., Lalonde, Girouard, & Letendre, 7379 St. Hubert St., Montreal, Que. (Apr. '56)

Graham, H. E., Water Plant Operator, Water Dept., 619 Laurens St., Camden, S.C. (Apr. '56) *P*

Grella, Anthony J., Meter Shop Operator, Sea Cliff Water Co., 325 Prospect Ave., Sea Cliff, N.Y. (Apr. '56) *MRPD*

Guglielmo, Vincent M., San. Engr., Gibbs & Hill, Inc., 11 W. 42nd St., New York, N.Y. (Apr. '56) *PD*

Harper, John D., A. J. Boynton & Co., 5907 N. Sheridan Rd., Chicago 40, Ill. (Apr. '56) *MD*

Haskett, James F., Mgr., Detroit Chlorinator Div., Fischer & Porter Co., 1436 Princeton, Berkley, Mich. (Apr. '56)

Hendy, Frederick; *see* Aspen (Colo.) Water Co.

Henley, E. F., Supt., Water Works, Box 141, Norphlet, Ark. (Apr. '56) *MRPD*

Hixson Utility Dist., William H. Beene Jr., Supt., Box 98, Hixson, Tenn. (Corp. M. Apr. '56) *M*

Hope, George, Asst. Supt., Water Dept., 27 Jerseyville Ave., Freehold, N.J. (Apr. '56) *MPD*

Hornsby, George C., Civ. Engr., Wiedeman & Singleton, 760 W. Peachtree St., Atlanta, Ga. (Apr. '56) *P*

Humboldt Munic. Water Dept., L. E. Lam, Supt., 1201 Main St., Humboldt, Tenn. (Munic. Sv. Sub. Apr. '56) *MD*

Hurko, Bohdan; *see* General Elec. Co. Range & Water Heater Dept.

Hutto, Leon B., Salesman, Choctow Pipe Co., 4901 Crestwood Dr., Little Rock, Ark. (Apr. '56) *D*

(Continued on page 112 P&R)

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PROVEN ON MANY SUCCESSFUL INSTALLATIONS.

The CARBALL is available in four sizes with capacities ranging to 10,000 lbs./CO_2 per day. Either gas or fuel oil may be utilized. Write for Bulletin 7W83.

OLD METHOD—Fuel is burned at atmospheric pressure resulting in the production of gases containing corrosive elements and taste imparting impurities. Cooling, scrubbing and drying generally removes only part of the undesirable products, and also some of the CO_2. Consequently, the compressor and diffusion system must handle corrosive gases which increases maintenance and reduces the life of the equipment.

CARBALL METHOD—The CARBALL produces CO_2 by compressing cold clean air followed by complete combustion of the air-fuel mixture, under pressure, in an accessible chamber. Corrosive elements and taste imparting impurities are eliminated. Cooler-Scrubber and Drier are not required. Recompression is eliminated since combustion under pressure permits self-injection of the gases.

ECONOMICAL AND EFFICIENT—Production and absorption of CO_2 with the CARBALL costs less than ¾ cent a pound as reacted. Fifty percent more CO_2 is produced as compared to old methods. DIFFUSAIR diffusion system generally yields in excess of 92% absorption efficiency at only 8 ft. submergence. One half minute retention time for absorption saves cost of large diffusion basin. Combustion efficiency permits fuel savings that will defray the cost of the CARBALL in less than seven years.

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(*Continued from page 110 P&R*)

Jefatura de Agua Potable y Alcantarillados, Rafael Rosell Coellar, Civ. Engr., Secretaria de Recursos Hidraulicos, Reforma 69, Mexico, D.F., Mexico (Corp. M. Apr. '56) *MRPD*

Jefferson Water Works, Edward Arbuckle, Supt., Water Plant, Jefferson, Iowa (Corp. M. Apr. '56) *MP*

Johnson, Rollie S.; *see* Knoxville (Iowa) Water Dept.

Jones, John N., Supt., Water & Sewage Plants, Indiana Reformatory, Box 28, Pendleton, Ind. (Apr. '56) *MP*

Karsten, Harold J., 6315 Brookside Plaza, Kansas City, Mo. (Apr. '56)

Kilgore, Clarence, Operator, Interstate Water Co., 141 N. Vermilion, Panville, Ill. (Apr. '56) *P*

Kinsey, James E., Foreman, Water Dept., Water Works Shop, 651—14th St., N.W., Atlanta 13, Ga. (Apr. '56) *M*

Klein, Alvin A., San. Engr., Water Safety Control, 3300 S. Cheltenham Pl., Chicago, Ill. (Jr. M. Apr. '56) *MP*

Knoxville Water Dept., Rollie S. Johnson, Supt., City Hall, 114 N. 3rd, Knoxville, Iowa (Corp. M. Apr. '56) *MRPD*

Kominek, Edward G., Gen. Sales Mgr., Infilco Inc., Box 5033, Tucson, Ariz. (Apr. '56) *P*

Kramer, Fred L.; *see* Coffeyville (Kan.)

Krempel, Roger E., Engr., Water Dept., City Hall, Janesville, Wis. (Apr. '56) *MD*

Lacy, Ilbert O., Supt., Water Treatment, Dept. of Public Works, 10 Felix St., Rochester 6, N.Y. (Jan. '56)

Lam, L. E.; *see* Humboldt (Tenn.) Munic. Water Dept.

Lang, George J., Supt., Constr. & Operation, Water Div., 2326 Fresno St., Fresno 21, Calif. (Apr. '56) *M*

Larsen, Hubert C., Supt., Water Works, Maxwell, Iowa (Apr. '56) *MPD*

Last, Bernard, Chief Engr., Rockwell Meters Inc., Box 512, Uniontown, Pa. (Apr. '56)

Lechtenberg, Victor J., Munic. Service & Supply, 612 Standard Oil Bldg., Omaha 2, Neb. (Apr. '56)

Lenox, Jacob L., Civ. Engr., 7 Nymph Rd., West Orange, N.J. (Apr. '56)

Lindeen, Leonard F., Foreman, Water & Sewer Dept., Box 143, Wilmette, Ill. (Apr. '56)

Linthwaite, Paul E., Vice-Pres. & Sales Mgr., Turbine Equipment Co., 63 Vesey St., New York 7, N.Y. (Apr. '56) *D*

Lowrance, W. A., Plant Operator, Water Dept., 300 N. Turner, City Hall, Hobbs, N.M. (Apr. '56) *M*

Lunt, Randle G., 248 S. Ave. 51, Los Angeles 42, Calif. (Apr. '56)

Mack, Leslie E., Graduate Student, Geology Dept., Univ. of Kansas, Lawrence, Kan. (Apr. '56) *R*

Mahaffey, John E., Cons. Engr., Box 122, Fayetteville, Ark. (Apr. '56) *RPD*

Maran, Edward C., Field Engr., Haskins, Riddle, & Sharp, Finance Bldg., Kansas City 6, Mo. (Apr. '56)

Marshall Water Works Inc., T. B. Tinsley, Pres., Marshall, Va. (Corp. M. Apr. '56) *MRPD*

Matsumura, Paul T., Civ. Engr., Water Dept., 425 Mason St., San Francisco 1, Calif. (Apr. '56) *D*

May, George I., Mgr., General Supply Co. of Canada Ltd., 27 Kipling Ave. S., Islington, Toronto 18, Ont. (Apr. '56)

Mayer, Robert L., Civ. Engr., Dept. of the Navy, Bureau of Yards & Docks, Washington 25, D.C. (Apr. '56) *MRP*

McCoy, Terence P., Salesman, Water & Sewage Works, 185 N. Wabash Ave., Chicago, Ill. (Apr. '56)

McDermed, Virgil, Supt. of Utilities, 308 W. Prairie St., Girard, Kan. (Apr. '56) *MRD*

McGonegal, Caron C., Sales Repr., US Pipe & Foundry Co., 681 Market St., San Francisco, Calif. (Apr. '56) *D*

Mequier, Bert, City Engr., 125 S. Washington, Dillon, Mont. (Apr. '56) *MP*

Mercer, Winfield R., Supt. of Water, 240 Globe St., Jackson, Ohio (Apr. '56) *MP*

Meyer, John William, Civ. Engr., Box 778, Blythville, Ark. (Apr. '56) *D*

Miller, John W., Supervisor of Mech. Maint., State Dept. of Conservation, 311 W. Washington St., Indianapolis, Ind. (Apr. '56) *PD*

Miller, Osborne T., Supt., Water Div., Dept. of Public Utilities, 225 Middleton S.E., Orangeburg, S.C. (Apr. '56) *PD*

Mitchell, Sidney B., City Engr., 1152 Suson Way, Sunnyvale, Calif. (Apr. '56) *MD*

Morrison, Joel R., City Mgr., Box 231, Waynesboro, Tenn. (Apr. '56) *M*

Morristown Water Works & Elec. Light Comrs., R. W. Pritchard, Mgr., Morristown, Tenn. (Munic. Sv. Sub. Apr. '56) *MPD*

Myrberg, Karl G., Sales Engr., Rockwell Mfg. Co., 1001 Peoples Gas Bldg., Chicago, Ill. (Apr. '56)

Nimtz, Roy E., Dist. Mgr., Rockwell Mfg. Co., 119 W. Denny Way, Seattle, Wash. (Apr. '56)

North Judson Water Dept., August G. Duser, North Judson, Ind. (Corp. M. Apr. '56) *MRP*

Palmore, Julian I., Jr., San. Engr., State Dept. of Health, State Office Bldg. Annex, Phoenix, Ariz. (Apr. '56) *PD*

Park Ridge, City of, James Galloway, City Mgr., 102 N. Northwest Hwy., Park Ridge, Ill. (Corp. M. Apr. '56) *MD*

Parks, Homer, Mgr., Water Works, Box J, Smackover, Ark. (Apr. '56) *MD*

Parsons Water Dept., Bernard T. Budd, Supt., Municipal Bldg., Parsons, Kan. (Corp. M. Apr. '56) *MD*

Passmore, Louis Spencer, Operator. Lakeview Water Co., Rte. 9, Box 1935, Waco, Tex. (Jan. '56) *M*

Patterson, Wren A., Supt., Water Works, Township of Niagara, Box 136, Queenston, Ont. (Apr. '56)

Plana Astienza, Luis, Civ. Engr., Calle Sta. No. 520, Apt. 6, Vedado, Havana, Cuba (Apr. '56)

Powell, Cloyd F., Sales Repr., Johns-Manville Sales Corp., Pipe Div., 832 Fisher Bldg., Detroit 2, Mich. (Apr. '56) *D*

Pritchard, R. W.; *see* Morristown (Tenn.) Water Works & Elec. Light Comrs.

Ramsden, William E., Supt., Rockwell Meters Inc., Corner Bailey & Gallatin Aves., Uniontown, Pa. (Apr. '56)

Richards, Kenneth E., Hydr. & San. Engr., Utility Eng. Co., 12345 W. 19th Pl., Denver 14, Colo. (Apr. '56) *RPD*

Roberge, Robert H., Munic. Engr., Box 10, Mont-Laurier, Labelle County, Que. (Apr. '56)

Roberts, Brian H., Field Engr., Fairbanks, Morse & Co., 6547 N. 32nd St., Omaha 12, Neb. (Apr. '56)

Roberts, K. G.; *see* Scottsbluff (Neb.)

Rodriguez, Joe R., Operator, Water Works, Raymondville, Tex. (Apr. '56) *P*

Root, William L., III, Sales Engr., Simplex Valve & Meter Co., 7 E. Orange St., Lancaster, Pa. (Apr. '56) *MP*

Rosalini, Joseph, Supt., Water Works, Box 186, Highwood, Ill. (Apr. '56) *P*

Rosell Coellar, Rafael; *see* Jefatura de Agua Potable y Alcantarillados

Roth, Martin L., Engr., Mulford Eng., 33 W. 16th St., Chicago Heights, Ill. (Apr. '56) *RD*

Roudabush, William S., Jr., Asst. City Engr., City Hall, Charlottesville, Va. (Apr. '56) *MRPD*

Russell, George W., Supt., Mountain Water Supply Co., 217 S. Main St., Greensburg, Pa. (Apr. '56) *MD*

St. Cloud Water-Sewage Utility, Henry Foehrenbacher, Foreman, Water Plant, City Hall, St. Cloud, Minn. (Corp. M. Apr. '56) *MP*

Sallwasser, George M., Engr., Marion L. Crist & Assocs., Inc., Union Life Bldg., Little Rock, Ark. (Apr. '56) *PD*

Schlensker, Edwin F., Asst. Pumpman, National Lead Co. of Ohio, Willey Rd., Fernald, Ohio (Apr. '56) *PD*

Scottsbluff, City of, K. G. Roberts, City Engr., 1818 Broadway, Scottsbluff, Neb. (Corp. M. Apr. '56)

Scudder, P. J., Engr.-Treas., Power Water & Sewerage Systems, Power Bldg., Shelleyville, Tenn. (Apr. '56) *M*

Seay, James Irby, Jr., Owner, Irby Seay Co., 516 Goodwyn Institute Bldg., Memphis, Tenn. (Apr. '56) *RPD*

(*Continued on page 114 P&R*)

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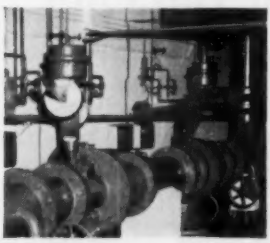

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Seevers, F. R., Sales Repr., Mueller Co., 1225 S. Glencoe, Denver 22, Colo. (Apr. '56)

Shields, Lewis S., Jr., San. Engr., Reynolds, Smith & Hills, Box 4817, Jacksonville, Fla. (Apr. '56) *MRPD*

Sindt, Howard T., Civ. Engr., Romine, Sindt & Snow, 319 Union Arcade Bldg., Davenport, Iowa (Apr. '56) *D*

Sisson, Loren R., Engr., Rincon del Diablo Munic. Water Dist., 144 W. 8th Ave., Escondido, Calif. (Apr. '56) *MD*

Skinner, Tommie A., San. Engr., State Health Dept., State Health Bldg., Little Rock, Ark. (Apr. '56)

Smith, Albert Ray, Contracting Engr., Pittsburgh-Des Moines Steel Co., 1015 Tuttle St., Des Moines 10, Iowa (Apr. '56)

Smith, Richard A., Engr. & Asst. Mgr., Vista Irrigation Dist., Box 696, Vista, Calif. (Apr. '56) *R*

Smith, William, Administrative Asst., Water Div., 312 City Hall, St. Louis 3, Mo. (Apr. '56)

Sniegocki, Richard T., Geologist, US Geological Survey, 515 E. 2nd St., Little Rock, Ark. (Apr. '56) *RP*

Spalding, V. B., Cons. Engr., Spalding, DeDecker & Assocs., 1405 S. Woodward, Birmingham, Mich. (Apr. '56) *RPD*

Stoutenberg, H. LaFond, Supt., Water Dept., Stamford, N.Y. (Apr. '56)

Stripe, Richard F., Civ. Engr., Black & Veatch, 4706 Broadway, Kansas City, Mo. (Apr. '56) *RP*

Sutton, Charles P., Sales Engr., Johns-Manville Sales Corp., 270 Madison Ave., New York, N.Y. (Apr. '56) *D*

Tallman, Louis E., Plastics Tech. Service Engr., Dow Chem. Co., 900 Wilshire Blvd., Los Angeles 17, Calif. (Apr. '56) *D*

Taylor, Scott D., Water Supt., Louisburg, Kan. (Apr. '56) *MRPD*

Thomas, A. L., Chief Engr., Public Utilities Com., Township of Toronto, Cooksville, Ont. (Apr. '56)

Tinsley, T. B.; *see* Marshall (Va.) Water Works

Train, G. F., Supt., Water Dept., 529 E. 4th St., Superior, Neb. (Apr. '56)

Tyra, Leo P., Dist. Engr., Bureau of San. Eng., State Board of Health, Little Rock, Ark. (Apr. '56) *RP*

Underwood, C. N., Div. Mgr., Water Dept., 600 E. Trade St., Charlotte, N. C. (Apr. '56) *M*

Vallee, Antonio, Box 187, Camaguey, Cuba (Apr. '56)

Van Mele, Peter C., Auditor, Water Works, 224 N. Main St., South Bend, Ind. (Apr. '56) *MRPD*

Vincitorio, Phillip, San. Engr., Water Purif. Div., Water Safety Control Sec., 3300 E. Cheltenham Pl., Chicago, Ill. (Apr. '56) *MP*

Wagner, Fred G., Supt., Water Works, 224 N. Main St., South Bend, Ind. (Apr. '56) *MPD*

Walker, Lewis Stanley, Jr., Designing Engr., Haskins, Riddle & Sharp, 1009 Baltimore, Kansas City, Mo. (Apr. '56) *PD*

Wallace, Cecil O., Asst. Supt., Light & Water Plant, Augusta, Ark. (Apr. '56) *M*

Waller, Robert O., Asst. Engr., Bureau of Water, Rm. 402 City Hall, Chicago, Ill. (Jan. '56)

Walters, John G., Sales Engr., Infilco, Inc., 1719 Mimosa Ave., Charlotte 5, N.C. (Apr. '56) *MRP*

Ward, John P., Jr., Field Editor, *The Dixie Contractor Magazine,* 508 Luckie St., N.W., Atlanta, Ga. (Apr. '56) *RPD*

Wauford, J. Roy, Jr., Owner, J. R. Wauford & Co., Lebanon, Tenn. (Apr. '56) *PD*

Weems, W. S., Mgr., Water & Sewer Systems, Box 19, Texarkana, Ark. (Apr. '56)

Westrick, Alleman J., Supt., Water Distr., City Hall, Marine City, Mich. (Apr. '56) *P*

Williamson, C. W., Vice-Pres. & Gen. Mgr., Trinity Valley Iron & Steel Co., 3400 Bryce St., Fort Worth, Tex. (Apr. '56)

Wingerter, Clayton L., Water Supt., 603 Chestnut St., Chester, Ill. (Apr. '56)

Wylie, F. Samuel, Jr., Partner, Farnsworth & Wylie, 314 Unity Bldg., Bloomington, Ill. (Apr. '56)

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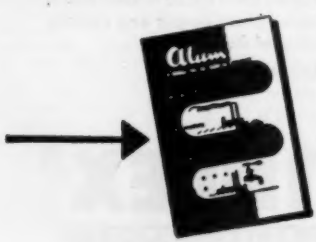

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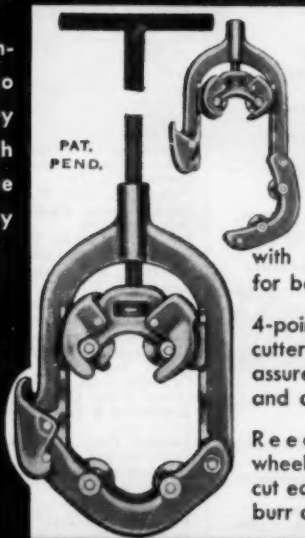

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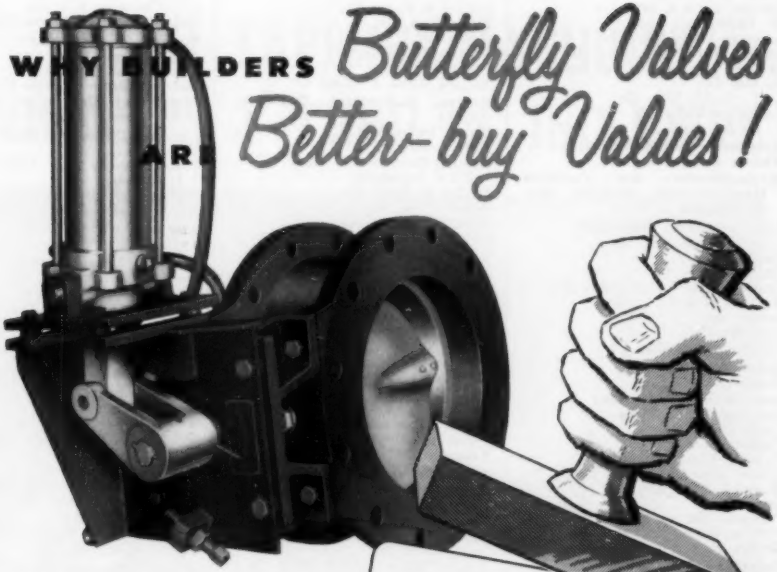

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Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe Vises:
Spring Load Mfg. Corp.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Morse Bros. Mchy. Co.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
Infilco Inc.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Morse Bros. Mchy. Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Fischer & Porter Co.
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.

Sodium Aluminate:
Monolith Portland Midwest Co.

Sodium Chloride:
Frontier Chemical Co.

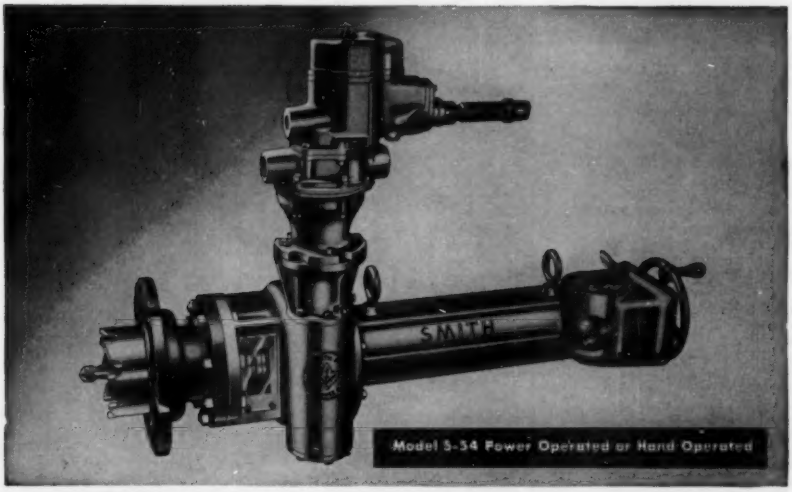
Sodium Hexametaphosphate:
Calgon, Inc.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.

SMITH TAPPING MACHINES FOR TAPS 2" THRU 12" INCLUSIVE



The NEW Smith S-54 Tapping Machine is the most modern, efficient and economical machine available. The Machine is used with Tapping Sleeves, Hat Flanges, Saddles and Tapping Valves to make 2" through 12" connections under pressure to Cast Iron, Cement-Asbestos, Steel and Reinforced Concrete Pressure pipe. Features: 1. Positive automatic feed insures correct drilling and tapping rate. 2. Travel is automatically terminated when tap is completed—cutter and shaft cannot overtravel. 3. Telescopic shaft reduces overall length. 4. Mechanism is housed in heat treated Aluminum Case filled with lubricant. 5. Stuffing Box and Packing Gland is accessible without disassembling machine. Line pressure cannot enter machine case. 6. Extra large diameter telescopic shaft add strength and rigidity. Timken radial—thrust bearings maintain alignment, reduce friction and wear. 7. Worm gearing operates in lubricant, torque is reduced to the minimum. 8. Cutters have replaceable Flat and Semi-V alternate teeth of High Speed Steel or Tungsten Carbide. 9. Flexibility: Hand Operated Machines can be converted to Power Operation by interchanging worm gearing. Bulletin T54 sent on request.

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THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon, Inc.
Cochrane Corp.
General Filter Co.
Infilco Inc.
Morton Salt Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.

Storage Tanks; see Tanks

Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
Johnson, Edward E., Inc.
R. D. Wood Co.

Surface Wash Equipment:
Cochrane Corp.
Permutit Co.

Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tanks, Steel:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries)
Cochrane Corp.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tenoning Tools:
Spring Load Mfg. Corp.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Shower Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
DeZurik Shower Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Simplex Valve & Meter Co.

Waterproofing:
Barrett Div.
Inertol Co., Inc.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Screens:
Johnson, Edward E., Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

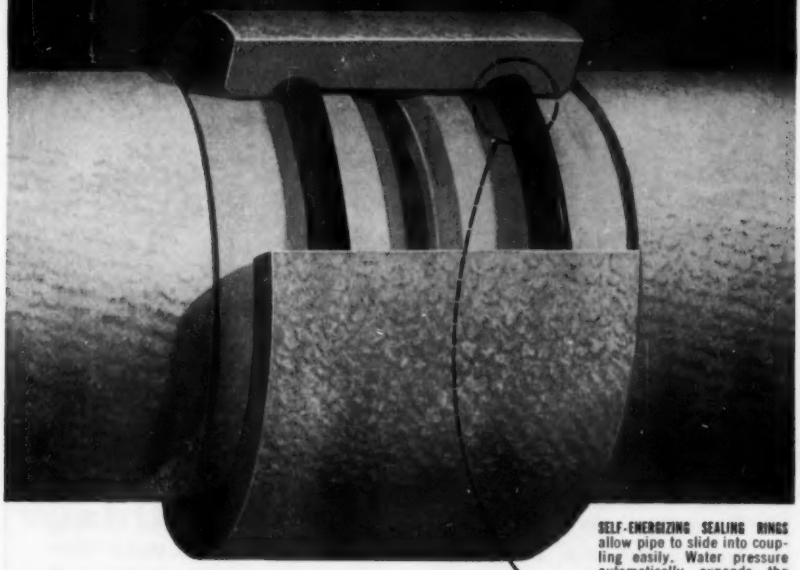
Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1955 AWWA Directory.

NEW!

"FLUID-TITE"® COUPLING*

For "Century®" Asbestos-Cement Pressure Pipe

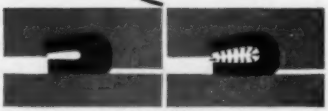


SELF-ENERGIZING SEALING RINGS allow pipe to slide into coupling easily. Water pressure automatically expands the rings. The higher the internal water pressure, the tighter the seal.

- **Cuts installation time**
- **Provides permanent, water-tight seal**

Now, using the new "Fluid-Tite" Coupling, crews can lay more "Century" Asbestos-Cement Pressure Pipe per hour than ever before. No cumbersome coupling pullers are needed. "Century" Pipe can be easily connected with standard valves, hydrants and fittings.

Thanks to the speed and simplicity of using "Fluid-Tite" Couplings, there is no need to hold up pipe-laying operations in rain, snow or wet trench conditions. Specify "Fluid-Tite" Couplings with "Century" Asbestos-Cement Pressure Pipe. You'll get more rapid installation, plus full flow and low maintenance. Write today for details.



New self-energizing "Fluid-Tite" sealing rings have tapered surfaces, and compress, to permit pipe to slide in easily.

When main is filled, rings expand with application of internal water pressure, creating a tighter seal.

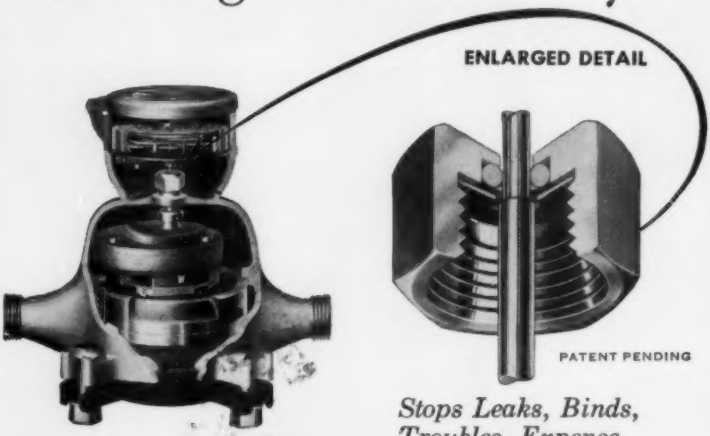
KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

"Century" Pipe and "Fluid-Tite" Couplings meet A.W.W.A., A.S.T.M., and Federal specifications and are approved by Underwriters' Laboratories, Inc.

*PATENT APPLIED FOR

K&M best in asbestos®

The Rockwell "O" -Ring Stuffing Box Assembly



Stops Leaks, Binds, Troubles, Expense

The Greatest Single Advance In Water Meter Construction In Years

Here's another outstanding development from Rockwell Research. It's a sure cure for all the headaches that go with meter stuffing box maintenance. Perfected four years ago, this Rockwell "O"-Ring Stuffing Box assembly has now been thoroughly field tested. *It won't leak; can't bind!* Meters with this construction run more freely, stay accurate longer. Worn spindles are a thing of the past.

Now *all* Rockwell water meters make use of this *exclusive* "O"-Ring design upon which patent application has been made. There's no extra cost for this construction, but a lot of extra satisfaction and value. Ask your Rockwell representative to demonstrate. And be sure to inquire about the use of "O"-Ring stuffing box nuts as interchangeable replacements for stuffing box assemblies in earlier model Rockwell meters.

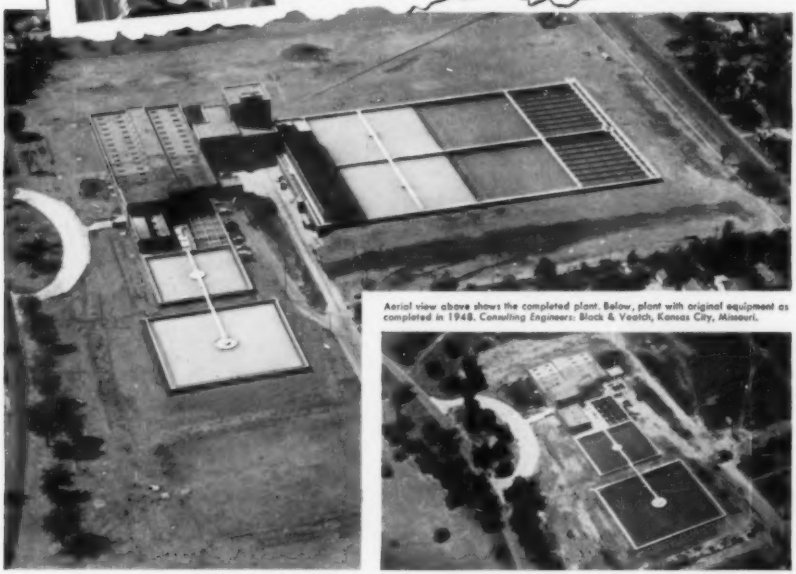
ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA. Atlanta Boston Charlotte Chicago Dallas Denver Houston Los Angeles Midland, Texas. New Orleans New York N. Kansas City Philadelphia Pittsburgh San Francisco Seattle Shreveport Tulsa. In Canada: Rockwell Manufacturing Company of Canada, Ltd., Toronto, Ontario

Water Treatment, too, needs

INDIVIDUAL DIAGNOSIS

No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.



Aerial view above shows the completed plant. Below, plant with original equipment as completed in 1948. Consulting Engineers: Black & Veatch, Kansas City, Missouri.

Wichita

KANSAS

Completes Modernization with Third Addition to Plant

Step 1 — In 1940, Wichita, Kansas, installed a Dorrco Flash Mixer, Dorrco Flocculator mechanism and a 115′ dia. Dorr Squarex Clarifier at their new plant with a design flow of 20 M.G.D.

Step 2 — In 1948 another Dorr Squarex Clarifier was installed, this time a 160′ dia. unit which increased capacity to 45 M.G.D.

Step 3 — The latest addition at Wichita's recently completed plant, includes the installation of two more sets of Dorrco Flocculators, and two 160′ dia. Dorr Squarex Clarifiers which have increased the plant capacity to 84 M.G.D.

If you'd like more information on the complete line of Dorr-Oliver Water treatment equipment, write for Bulletin No. 9141 to Dorr-Oliver Incorporated, Stamford, Connecticut.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

Flocculator and Squarex T.M. Reg. U. S. Patent Office

DORR-OLIVER

INCORPORATED

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

STAMFORD • CONNECTICUT • U.S.A.

LEADITE

Trade Mark Registered U. S. Pat. Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking